Tigray Agricultural Research Institute (TARI)
Agricultural Growth Program - II (AGP-II)

AGRICULTURAL GROWTH PROGRAM

The Role of Blended Fertilizers in Enhancing Productivity and Quality of Crops in Ethiopia

Proceedings of the National Workshop held 07- 08 June 2019, Axum Hotel, Mekelle, Ethiopia

Editors:
Fisseha Hadgu
Bereket Haileslassie
Hintsa Libsekal
Sofonyas Dargie
Abbadi Girmay
Mitiku Haile

Members of Workshop Organizing Committee

Fisseha Hadgu (PhD)

Bereket Haileslassie (PhD)

Hintsa Libsekal (MSc.)

Sofonyas Dargie (MSc.)

Daniel Hailu (BA)

Tsadik Tadele (MSc.)

Teame Shimgabr (MSc.)

The Role of Blended Fertilizers in Enhancing Productivity and Quality of Crops in Ethiopia

Proceedings of the National Workshop held 07-08 June 2019, Axum Hotel, Mekelle, Ethiopia

Editors:
Fisseha Hadgu
Bereket Haileslassie
Hintsa Libsekal
Sofonyas Dargie
Abbadi Girmay
Mitiku Haile

The Role of Blended Fertilizers in Enhancing Productivity and Quality of Crops in Ethiopia

January 2020
ኢምሕት፤ 2012
Website: http://www.tari.gov.et
Tel: +251-0344-417798
Fax: +251-0344-408028
P.O.Box: 492
Mekelle, Tigray, Ethiopia

Correct citation: Fisseha Hadgu, Bereket Haileslassie, Hintsa Libsekal, Sofonyas Dargie, Abbadi Girmay, and Mitiku Haile (eds.) 2020. Proceeding of national workshop: The Role of Blended Fertilizers in Enhancing Productivity and Quality of Crops in Ethiopia, 07-08 June 2019, Axum Hotel, Mekelle Ethiopia. Tigray Agricultural Research Institute and Agricultural Growth Program-II, Mekelle, Ethiopia.

ISBN: 978-99944-77-46-3

Donors and partners

Acknowledgements

The workshop and this proceeding materialized due to the contribution of many institutions and people to whom Tigray Agricultural Research Institute (TARI) bestows the pleasure of expressing its appreciation and gratitude. Tigray Agricultural Research Institute would like to thank Mr. Sofonyas Dargie for bringing the idea of organizing a workshop on blended fertilizer. Natural Resource Research Diretorate of TARI is highly appreciated for the active engagement in the realization of the workshop and in the finalization of the proceeding. Tigray Agricultural Research Institute would also like to express utmost gratitude to Agricultural Growth Program (AGP-II), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and Mekelle Soil Research Center (MSRC) for their financial support to undertake the workshop. Staffs of TARI, Mekelle Soil Research Center and Shire Soil Research Center are acknowledged for facilitating the workshop. Agricultural Growth Program (AGP-II) deserves special gratitude for the financial support for some of the experiments and publication of this proceeding. Tigray Agricultural Research Institute is also indebted to members of the Conference Organizing Committee for cooridinating a successful workshop. The contributions of paper presenters, chair persons, panalists and participants are highly appreciated. Finally, the Institute appreciates and thanks His Exellency Dr. Atinkut Mezgebo (Head,Tigray Bureau of Agriculture and Rural Development) for delivering the opening speech, Professor Mitiku Haile for his Keynote Address, Dr. Selamyhun Kidanu and Dr. Tilahun Amede for their presentations of invited papers and Dr. Birru Yitaferu for his closing remark. Last but not least TARI would like to acknowledge Mr. Asfaw Nigus (Tigray Bureau of Agriculture and Rural Development, Senior Soil Fertility expert) for his contribution in the way forward of this proceedings.

Opening Speech

Low soil fertility is among the various problems encountered in agriculture that caused low crop productivity in Ethiopia. It is to be noted that use of chemical fertilizers in Ethiopia contributed to crop yield increment, although there is a need for further improvement. In Ethiopia, soil fertility and fertilizer studies were initiated in the 1960s by undertaking fertilizer experiments by different actors. The application of chemical fertilizers is the practice applied at scale to date, especially on nitrogen (N) and phosphorus (P). However, due to depletion of nutrients by their continuous uptake by crops without replacing them as well as because of loss of plant nutrients by water erosion, the essential plant nutrients other than N and P have become limiting factors for crop production in most part of the country. As a strategy to contribute to the Growth and Transformation Program (GTP1) of our country, "Soil Fertility Status and Fertilizer Recommendation Atlas" have been developed by Agricultural Transformation Agency (ATA) and Ministry of Agriculture (MoA) for four regions in the country. The atlas of Tigray Region was published in 2014 containing soil fertility status and fertilizer recommendations at Woreda and Kebele levels. Experiments to determine rates of the recommended fertilizer types were being conducted by different federal and regional research institutions as well as by universities to rectify the recommendation domains.

The Tigray Agricultural Research Institute organized this National Workshop on 'The Role of Blended Fertilizers in Enhancing Productivity and Quality of Crops in Ethiopia' to be held during these two days. The workshop is initiated with the intention of evaluating the research results being conducted by the different institutions, thereby to summarize and publish the findings so that the recommendations will be useful for smallholder farmers to increase crop productivity in Tigray as well as in the country. Taking this into consideration, I expect that this workshop will achieve the intended goals and declare that the workshop is officially open.

Atinkut Mezgebu (PhD)
Head, Tigray Bureau of Agriculture and Rural Development
Mekelle, Ethiopia

Foreword 1

Tigray Agricultural Research Institute (TARI) convened this national workshop on blended fertilizer with a theme 'The Role of Blended Fertilizers in Enhancing Productivity and Quality of Crops in Ethiopia' at Mekelle from 07-08 June 2019. The event was very colorful. Participants were drawn from four Universities in Tigray (Mekelle, Axum, Adigrat and Raya), Technical Vocational Education and Training (TVETs), Regional Agricultural Research Institute (TARI, Amhara Agricultural Research Institute, Afar Pastoral and Agro-pastoral Research Institute), Ethiopian Institute Agricultural Research (EIAR), Ministry of Agriculture and Natural Resources, Ethiopian Agricultural Research Council Secretariat (EARCS), GiZ, OCP and International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). The main focus was how to deliver the right fertilizer to Ethiopian farmers. What we have gone through our research approaches was for multiplier effect, harmony, integration, synergy and partnership and the way forward for enhancing integrated soil fertility management (ISFM) in support of agricultural transformation. Soil fertility and soil health for sustainability should be incorporated in fertilizer recommendations. The workshop was officially opened by the Guest of Honor, H.E. Dr Atinkut Mezgebo, Head, Tigary Bureau of Agriculture and Rural Development.

Main issues discussed include:

1. Keynote address by Prof. Mitiku Haile (MU)
2. Iinvited papers by Dr. Tilahun Amede (ICRISAT) and Dr. Selamyihun Kidanu (OCP)
3. Twenty three Scientific papers of which 18 and 5 were oral and poster sessions respectively were presented
4. Plenary discussion on the way forward

Major outputs:

1. This proceeding summarises, consolidates and synthesizes the deliberations.
2. Platforms local to international levels
3. Capacity building
4. Linkage between research and development
5. Site-specific and wider area recommendation to be packaged

This workshop and its output as a proceeding will add value to the nation wide initiative on delivering the right information, share data and continue building on existing knowledge, and fruitful collaboration and partnership at all levels.

Abbadi Girmay Reda (PhD)
Director General
Tigray Agricultural Research Institute
Mekelle, Ethiopia

Foreword 2

Addressing food and nutrition security, climate resilience and agricultural transformation requires investments on knowledge and technology development. To this effect, Tigray Agricultural Research Institute (TARI) has been involved in adapting, generating and promoting agricultural technologies that enhance food security, supply inputs to agro-industries and generate foreign currency. TARI has five technical research Directorates (Natural resource research, Crop research, Livestock research, Socio-economics and extension and Agricultural mechanization and rural energy research) involving in different research agendas to sustain supply of agricultural technologies.

Natural resources research directorate (NRRD) is conducting research activities in different agro-ecologies and farming systems organized by five research processes: Soils research; Irrigation, drainage and water harvesting; Forestry and agroforestry; Soil and water conservation; Watershed, GIS and Agro-meteorology. Under the soils research program, the two Soil Research Centers based in Mekele and Shire and soil research case team based in Humera are undertaking different research activities. Development of soil test based fertilizer recommendation packages for major crops and soil types, improving utilization of organic and bio fertilizers, salt affected soils, Vertisols and acid soils management are among the focus areas for soils research.

As part of the Growth and Transformation Program, government has shown commitment to support soil based fertilizer application through development of atlas for soil fertility status and fertilizer recommendation. Soil research program under TARI was expected to identify rates for the recommended blended fertilizers based on the atlas. Accordingly, soil researchers were engaged in indentifying rates of different blended fertilizers on major crops for the last four years. As a result, national workshop has been organized with a theme 'The Role of Blended Fertilizers in Enhancing Productivity and Quality of Crops in Ethiopia' at Mekelle from 07-08 June 2019 as output of the last four years endeavour. Papers presented in the workshop are published on a proceeding and will be distributed to end users and stakeholders for further value addition in the arena of soil research.

Kinfe Mezgebe
Director, Natural Resources Research Directorate
Tigray Agricultural Research Institute
Mekelle, Ethiopia

Preface

Declining soil fertility is among the major crop constraint that limits productivity and production in Ethiopia. This could be due to poor crop rotation practices, inefficient soil and water conservation undertakings and absence of site specific soil test based fertilizer applications. For this reason, ATA and MoA investigated the soil fertility status and mapped nutrient levels to formulate the required type of blended fertilizers. Research institutes are also trying to validate the respective recommended blended fertilizers types and rates for specific sites and crops. Aligned with this, the Agricultural Growth Program (AGP-II) supported in undertaking blended fertilizer experiments by Mekelle and Shire Soil Reseach Centers since 2017. This proceeding has included the results of research works on blended fertilizers by the Soil Research Centers as well as by other research institutes and universities. Agricultural Growth Program (AGP-II) has financially supported to undertake the workshop on blended fertilizer and to publish this proceeding.

Therefore, as AGP-II coordinator for research, I would like to thank the researchers and presenters that have been dealing with validating the blended fertilizer and come up with the results. I would also like to recommend the policy makers to use the output of this proceeding to revise the strategy on fertilizer recommendations.

Desalegn Emuru Yeibyo
Tigray Agricultural Research Institute
Coordinator, AGP-II, Research Component

Table of contents

Keynote Addresses

Cherishing Ethiopian Soils for Sustainable Agricultural Production: Healthy Soils for Healthy and Productive People

Mitiku Haile /Professor/

Mekelle University, P.O. Box 231, Mekelle Ethiopia
Correspondence: gualmitiku@yahoo.com

Keynote address delivered at the National Workshop on Blend Fertilizer to Enhance Productivity and Quality of Crops.
Organized by Tigray Agriculture Research Institute.
7-8 June, 2019
Mekelle, Tigray

Background

This keynote address is based on the reports made by Professors Mitiku Haile and Eric Smaling at the Adama workshop held on 17 October 2017 and in Hawassa on 22 September 2018 that discussed on issues and constraints of blend fertilizers recommendations and a snapshot of national achievements in approaching soil fertility, fertilizer blending and the agronomic efficiency of fertilizers, respectively.

According to the 1984 Provisional Soil Association Map of FAO, Ethiopia is endowed with diverse agroecologies and soils. Although estimates vary with survey scale, major agricultural soil groups are Leptosols 17%, Nitosols 12%, Cambisols 11.6%, Regosols 10.9%, Vertisols 10%, Fluvisols 8% and Luvisols 6%.

Soils of Ethiopia are constrained due to several attributes but the major ones are: low productivity of soils that require special attention (Vertisols, acidic soils, salt affected soils, shallow soils, soils with low organic matter content), inappropriate irrigation methods that increase salinity, limitations in the use of organic fertilizers, unsatisfactory results from mineral fertilizer application (rainfed and irrigated) and soil degradation and pollution.

Growth in the agriculture sector is an important component of the Government of Ethiopia's Growth and Transformation Plan (GTP) II. As soil fertility is a pre-requisite for agricultural growth, new policies and large investments have been made to modernize soil fertility management in Ethiopia. Central to these is development of blended fertilizer supply chains.

Agriculture remains a pivotal sector for economic growth and human development in Ethiopia. Gross domestic product (GDP) from agriculture accounts for 41.6% of the total GDP. National exports are dominated by agricultural products and more than 80% of the population in Ethiopia depends on agricultural production for their livelihood. The Ethiopian Government remains highly committed to promoting soil fertility as a prerequisite for achieving the development targets for agricultural productivity and GDP growth set forth in the GTP II.

Soil fertility and nutrient management is fundamental to maximizing crop yields and sustaining agricultural productivity. Conversely, it is well established that low soil fertility reduces agricultural production, incomes and food security. In agriculture-based economies like Ethiopia's, low soil fertility retards economic development at local and national levels.

Over the past 15 years Ethiopia's average agricultural growth rate has been close to 7% per annum. Targets in the GTP II call for 8% annual growth from the agriculture sector. To this effect the government has demonstrated strong commitment to the sector through allocation of more than 15% of the total public expending to agriculture and rural development, surpassing Comprehensive Africa Agriculture Development Program (CAADP's) standard of 10% of total expenditure in agriculture sector, despite constraints in foreign currency, fertilizer remains one of Ethiopia's top imports.

Recognizing the fundamental role that soil fertility plays in agricultural growth, Ethiopia has promoted use of mineral fertilizer for more than 55 years. The Freedom from Hunger Campaigns of the 1960s led to the first nation-wide mineral fertilizer recommendations. For decades, Ethiopia maintained a blanket, nation-wide fertilizer recommendation of 100 kg DAP (Di-ammonium Phosphate: 18% N, 46% P_2O_5) and 100 kg urea (46% N) per hectare based on the Freedom from Hunger Campaign and on-farm fertilizer trials in the mid-1960s. Later, with the advent of farming systems research and support of the National Fertility Inputs Unit (NFIU) of the FAO, the recommended rate was revised to 150 kg DAP and 100 kg urea per hectare.

In recent years, and particularly since 2014, several significant developments backed by large investments to transform the soil fertility sector of Ethiopia have been initiated. Total volumes of imported fertilizer have risen dramatically. Prior to 2008 fertilizer imports did not exceed 500,000 metric tons, this year, Ethiopia will import one million metric tonnes (Ministry of Agriculture, 2018).

Nutrient diversity in imported fertilizer has also increased. Until 2013, only urea and DAP containing N and P were imported to Ethiopia. In light of global research and studies from Ethiopia indicating that application of N and P fertilizer alone can lead to mining and stock imbalances of other important soil nutrients. Ethiopia has shifted from promoting fixed amounts of urea and DAP towards policy and supply chain development for site-appropriate multi-nutrient blended fertilizer. To capacitate this shift, the following notable initiatives have been made:

1. The EthioSIS (Ethiopian Soil Information System) project was launched. EthioSIS informs site-appropriate blended fertilizer application by compiling information on limiting nutrients from topsoil data into local soil fertility maps and recommendations.

   EthioSIS is among the first initiatives of its kind in Africa, employing remote sensing satellite technology and other state-of-the art techniques for soil surveying. Wet chemistry analysis using instruments with high-detection limits are utilized, as are rapid, non-destructive infrared spectroscopy and laser diffraction particle size distribution analysis techniques. Soil data is compiled into a database. Using this soil data and critical levels for nutrient deficiency selected from international literature, maps of soil type and soil fertility requirements are compiled. EthioSIS allows for soil-based fertility recommendations with Woreda- and Kebele-level specificity. At this time, soil fertility atlases have been prepared for the four highest producing regions of the country; Amhara, Oromiya, Southern Nations Nationalities and Peoples (SNNP) and Tigray. In the future, soil fertility mapping will extend to other regions.

2. Five domestic fertilizer blending facilities in regionally-based cooperative unions were established to prepare locally-appropriate blended fertilizers from inputs imported by the Agricultural Business Corporation (ABC). These blending facilities combine NPS base fertilizer with supplementary nutrients (such as K, Zn B, Cu and Fe) as recommended by EthioSIS fertility maps.

Each blending plant has a capacity of 500,000 million tonnes per year; the output is expected to benefit millions of farmers.Unions distribute their blended fertilizer through primary cooperatives, which are proving effective in reaching smallholder farmers in remote places. The five fertilizer blending facilities have been established in four regions of the country: Tigray, Oromiya, Amhara and SNNP. Future plans include increasing the national number of blending facilities to twelve.

Complimentary to developing nutrient management through holistic development of blended fertilizer supply chains, several initiatives to promote a more systems-approach to soil health and sustainable resilient farming systems are ongoing. These include initiatives to scale up sustainable land management (SLM), reclamation of acidic soils, improvement of the productivity of waterlogged soils, increasing capacity for climate smart agriculture (CSA) and integrated soil fertility management (ISFM) and community based participatory watershed development (CBPWD) to rehabilitate degraded lands. A national Soil Health and Fertility Amendment Strategy was developed by the Soil Fertility directorate of the Ministry of Agriculture and Natural Resources, seeking to satisfy food security and contribute to economic growth through integrated evidence-based soil management that recognizes landscapes, farming systems, cropping systems, and ensuring that technologies and practices reach end users. In concert with nutrient management initiatives and promotion of quality seed, these efforts collectively result in higher yields from the same land per season, healthier and more fertile soils, climate change adaptation and mitigation, and more sustainable farming systems.

Emerging technical and agronomic issues in production and use of blend fertilizers.

Strengths of Ethiopia’s new blended fertilizer supply chain are several, including leapfrogging upon international soil fertility research ,international collaboration for large investments required (organized through AGP II,), and achievement of lower than regional average fertilizer prices to end users due to government bulk purchasing and distribution through the cooperative system.

Limitations in application of critical level approach to fertility recommendations

EthioSIS applies the critical level approach in determination of fertility recommendations from topsoil data. A critical level is the soil fertility level below which a decline in crop productivity may be expected (Figure 1). The selection of critical levels of soil nutrients has far-reaching consequences in terms of determining deficiency or sufficiency of soil nutrient stock, and subsequent fertility recommendations. Ethiopia's critical levels have been set largely based on international literature due to absence of field data on fertilizer-crop response from Ethiopia.

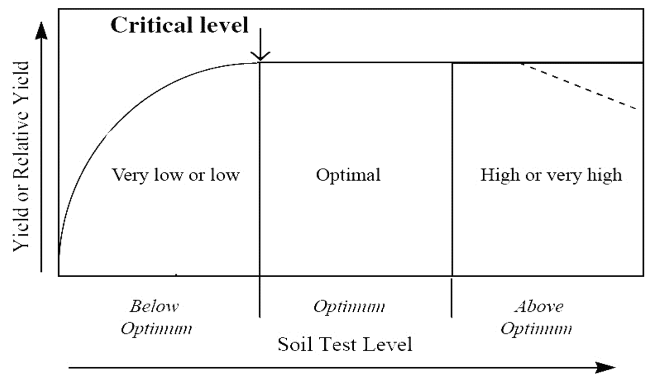

Figure 1. Critical levels represent the minimum nutrient level below which decline in crop response is observed

In the case of boron for example, a relatively high critical level has been selected, rendering 89% of the country to be considered as boron deficient. Boron is included in blends developed for areas identified as boron-deficient, yet preliminary data indicate that blends that do not have boron (and therefore have greater levels of macronutrients N and P) tend to perform better than blends that do have boron. For example, in on-farm and FTC trials in SNNP region which is classified as 'boron deficient' as per selected critical levels, blends with boron perform less well than blends without boron in 5 out of 6 cases.

Furthermore, it is interesting to observe that critical levels selected for some plant nutrients are on the higher range of recommended literature values (as is the case for boron), while others tend to be on the lower side of recommended values in literature (as is the case for potassium). Other micronutrients and elements have no assigned critical level at all, as is the case for molybdenum (Mo) and selenium (Se), which play important roles in nitrogen fixation, and in the health of livestock and humans, respectively.

Insufficient N and P nutrients applied in fixed ratios

The current body of knowledge shows that N and P remain lead nutrients in realizing high crop yields. Additional nutrients in blends can subtract from N and P's impact on yield. Other nutrients beside N and P will become increasingly profitable when soils are being mined, after continuous cultivation with N and P fertilizers, and more effort to avail blended fertilizers should be made at a future time. Furthermore, recent data into Ethiopian crop response to blended fertilizer shows that blended fertilizer tends to have greater impact than N and P (urea and DAP) on research sites, while on farmer fields the impact of blended fertilizer tends to be not so marked (Kaizzi et al 2017).

Additional farm-level environmental variables influencing the impact of fertilizer on yield not considered in fertility recommendations

Agronomic factors at the field level, environmental factors at the landscape level, and a series of socio-economic variables all influence the capacity for soil fertility amendments to impact agricultural productivity. At a farm and landscape level, soil type is critical in influencing fertilizer response, but crop type, presence of organic matter, soil pH, salinity, rootable depth, water holding capacity and susceptibility to water logging also play a role in the effectiveness of the transfer of nutrients to plants. Several of these factors are influenced by land use, hydrogeology and landscape morphology.

Large-scale, landscape-level commonalities in socioeconomic or fertility-influencing factors may be observed and captured in regional level recommendations, but local variation is important to consider. Adjacent plots may have varying local conditions due to geographic variation or difference in historic land use and land management practice, or financial capacity or agricultural practice of farmers. For instance, neighboring plots may exhibit differences in drainage and sheet erosion because of geographic positioning on the landscape if one is on a slope and one in a valley bottom. Difference in soil organic matter or pH may arise due to variations in past practice of agroforestry (which tends to maintain carbon), or application of DAP (which tends to acidify soil).

For example, areas with sheet erosion immediately loose the benefits of fertilizer, so recommended fertilizer should be modified accordingly, and accompanied by soil stabilization measures. Crop management practice can also influence crop response to fertilizer.

Financial profitability, finance and risk

Even when fertility recommendations have favorable impact on productivity, farmers may not experience financial profitability from fertilizer investments. Local market factors including site-specific costs of inputs and prices for crops on local markets from crops determine farmer profitability. Other financial concerns, including access to finance and willingness to take risks influence also have a role to play in influencing farmer investment in fertilizer.

Quality of blended fertilizer

Several urgent quality control issues are apparent, both at the level of imported input supply, and at the level of output content (mineral content of blended fertilizer). Ensuring that inputs with correct specifications for blending are delivered to blending facilities is essential for blend quality as well as worker health and protecting the blending machinery from damage. At times inputs labeled as "granular" are actually powdery in form. Failure to maintain input standards has resulted in millions of dollars of losses in terms of ruined equipment and unusable inputs. When quality control at factory level does alert of quality breaches, communication between quality controllers and factory managers tends to be too late for alternatives to be sought.

Discrepancies between the labels and the actual chemical content of multi-nutrient fertilizers delivered to farmers are highly variable: sometimes the difference observed has been quite small, but sometimes it has been over 40%. When blended fertilizer samples collected from three blending factories (Becho Woliso, Enderta, and Setit Melik) were analyzed at the Horticoop laboratory, major inconsistencies were noted. For example, NPS was $16N\text{-}18P_2O_5\text{-}7S$ suggesting 53% less, which is not consistent with standard composition indicated in the fertilizer label: 19 N – $38P_2O_5+7S$. This revealed that P_2O_5 was 53% less than the standard analysis which seriously affected crop performance (e.g., maize) on red soils (e.g., Luvisols) that are highly phosphate fixing soils. In the same manner, levels of B and Zn are higher than the standard formula. In samples from two of the three blending facilities, N contents in NPSZn blend are considerably lower than N content in NPS-only, which cannot be attributed to the addition of Zn. (K was not monitored). Blended fertilizer factories do not have functioning laboratories and quality control mechanism because they do not have the necessary reagents for fertilizer analysis.

The impacts of differences in intended and applied nutrient levels can cause problems ranging diminished impact on crop productivity, to very serious losses including crop failure and soil toxicity. In 2016 farmer-research in Hawassa cluster teams of Capacity Building for Scaling Up of Evidence Based Best Practices in Agricultural Production in Ethiopia (CASCAPE) experienced complete maize crop failure in three Woredas as a result of the deficiency of phosphate in the fertilizer when applied in high phosphorus demanding soils of the region.

Key recommendations

In light of challenges and opportunities in the soil fertility sector discussed above, several interventions to improve the sector are discussed below.

Collect Ethiopian field data on crop response to inform fertility recommendations

It is important that fertility recommendations are continually fine-tuned to reflect Ethiopian crop response patterns and are grounded in data. Available statistical data should be mined and managed. In addition, well organized on-farm and research station trials should be done on a short and long-term basis to generate a robust data base on crop response to different fertilizer blends in different agroecologies.

Crop production is a function of the interplay of and ratio between different nutrients and several other factors, and 'deficiency' does not always mean crop growth is impaired without its addition in fertilizer. For example, the most limited nutrient in the system can prevent the uptake of other, more available nutrients, whether they are classed deficient or not.

The practical value of fertilizer recommendations is limited without validation in field trials. More evidence has to be gathered during the coming 5-10 years to verify that blends do the job they are expected to do. This can lead to gradual improvements that do not have to harm the system as it has been introduced now.

For the major crop/soil types in the country, it would be of benefit to set up (i) a long-term researcher-managed factorial fertilizer trial (model sites) on the major soil types, and (ii) in Woredas and Kebeles, specific omission trials to check on the yield-increasing effect of each nutrient in farmers' fields. A model such as Quantitative Evaluation of the Fertility of Tropical

Soils (QUEFTS), relating soil test values to actual nutrient uptake and crop yield, could be further developed to meet the Ethiopian conditions.

Researchers should be trained to get the most out of field trials. Trial designs have to be crystal clear with a clear explication of application rates that allows comparison, secondary data have to be gathered that can be used to explain differences in crop performance (rainfall, waterlogging, nutrient uptake). Lastly, statistical significance is important, yet yield increases that do not come out 'significant' may still be sufficiently interesting for certain farming communities or recommendation domains.

Continue to emphasize N and P in fertilizer recommendations and supply

To reflect the dominant role that N and P continue to have in crop response, it is important to resume focus on N and P nutrients in fertility recommendations and fertilizer supply, and also make fertilizers with different N: P ratios available.

Generate and compile data on other variables that influence benefits from fertilizer, including environmental and economic variables

Site-specificity in fertilizer recommendations can be further fine-tuned to include consideration of variables such as crop selection, local profitability based on fertilizer and commodity prices, acceptable risk levels, crop management practice, and local environmental factors such as soil organic matter, pH, drainage and soil erosion, all of which may be affected by landscape-level variables or historic land use patterns. It is suggested to have a ready accessible databases on these variables developed, e.g. databases on the types and prices of fertilizers (specified per kg N, P, etc.) and commodity prices per region, Woreda, and per year.

Improving access to available data, and capacity to use it

EthioSIS is a landmark initiative that characterizes the soil fertility dynamics at the level of regions, Woredas and Kebeles. There are some limitations in accuracy due to scale, and in representativeness of sampling points due to the grid approach, but it provides an invaluable basis and point of departure for further refinement in soil information and fertility recommendations.

Farmers, Bureau of Agriculture staff and even researchers have difficulty accessing and understanding the data, maps and recommendations of EthioSIS. Accessibility and capacity building to better make use of available data is necessary to increase incorporation of available data into agriculture at different levels.

Technical support to blending Factories Cooperatives and Unions

Factories Cooperatives and Unions (FCUs) need assistance in developing skills in order to run the blending plants in an effective and profitable way. Different blending facilities have different capacity building needs: some require support to manage and maintain machinery, and others need skills in business management, while others need support to develop quality control protocol. Formal assessment of capacity building needs at different blending factories should be conducted, and technical assistance to develop required capacity should then be availed accordingly.

Use of laboratories to monitor chemical content of blends

Distributors at the cooperative level and users at the farm level should be aware that quality blended fertilizer consists of two or more particulate granular materials of fairly uniform size and density, in consistent proportions. Visible red flags regarding quality include segregation of blended materials, or materials in different size/form (e.g. granular materials mixed with powder). These actors should also be aware of quality checking and reporting mechanisms.

At port of entry into the country, quality of inputs should be monitored to ensure the right mineral and the correct granular form. Before disseminating blended fertilizer to farmers, FCUs should make use of plant laboratories to test the quality and content of blends, and ensure accuracy of labeling. This will allow farmers to make informed nutrient applications on their fields.

Institutional experience sharing and capacity building

Different blending plants in different parts of the country are having different levels of success in terms of managing quality and profitability. Management and staff from different facilities could increase their efficiency by sharing lessons learned and developing skills together. The learning and documenting of Ethiopian experience will assist in ensuring that future blending facilities are efficiently run.

International blending knowledge and experience sharing could also be beneficial for Ethiopian blending factories. Blending is becoming more and more common in African countries. There is a good body of knowledge on blending. Particularly the International Fertilizer Development Center (IFDC) has been involved in this field. IFDC is in a good position to evaluate successes and failures of blend fertilizer development and hick-ups in the entire input supply chains. The Alliance for a Green Revolution in Africa (AGRA) has a Soil Health programme in several African countries that includes fertilizer technology and marketing. It is also involved in quality control at the level of ports. The African Fertilizer and Agribusiness Partnership (AFAP) can also be quite a useful partner. (http://www.afap-partnership.org/)

Stronger linkages between agriculture sector stakeholders

The fertilizer sector needs to be embedded in a sound system of delivery of agricultural services, including ready access to input and output markets, sound systems of saving, credit, floor prices and crop insurance, strong cooperative structures, parallel attention for integrated crop, nutrient and land/water management, and adequate linkages to research and extension.

Conclusion

Fertility management is critical to the productivity of the agricultural sector. Despite acute foreign exchange shortages, fertilizer remains one of Ethiopia's top import items. Out of concern to maximize the positive impact of blended fertilizers on agricultural productivity, the following key issues and recommendations are identified to:

I. Fine-tune fertility recommendations and

II. Improve quality of blended fertilizers.

References and recommended readings

CSA (Central Statistics Agency) (2013): Agricultural Sample Survey 2012/2013 Volume I. Report on area and production of major crops (private peasant holdings, Meher season). Statistical Bulletin 532, Addis Ababa, as cited in Negash Demissie and Israel Bekele. 2017. Optimizing Fertilizer Use within an Integrated Soil Fertility Management Framework in Ethiopia. In: Fertilizer Use Optimization in Sub-Saharan Africa. Charles S. Wortmann and Keith Sones (eds). CAB International, Nairobi, Kenya, pp. 52.

Ethiopian Institute of Agricultural Research (EIAR), Overview of the Growth and Transformation Plan http://www.eiar.gov.et/index.php/agricultural-growth-program-ii, last accessed February 21, 2018.

Kaizzi KC Mohammed MB and Nouri M (2017): Fertilizer Use Optimization: Principles and Approach. In: Fertilizer Use Optimization in Sub-Saharan Africa. Charles S. Wortmann and Keith Sones (eds). CAB International, Nairobi, Kenya, pp.9.

Ministry of Agriculture and Natural Resources (2017): Soil Health and Fertility Amendment Strategy, Addis Ababa.

Udo de Haes HA Voortman RL Bastein T Bussink DW Rougoor CW van der Weijden WJ (2012): Scarcity of micronutrients in soil, feed, food, and mineral reserves. Urgency and policy options. Platform Agriculture, Innovation & Society, the Netherlands.

Invited Papers

Invited Paper 1

Targeting Blended Fertilizers for Enhancing Productivity in the Ethiopian Highlands

Tilahun Amede (PhD)

Principal Scientist, International Crops Research Institute for the Semiarid tropics (ICRISAT).
Correspondence: T.amede@cgiar.org

Invited paper delivered at the National Workshop on Blend Fertilizer to Enhance Productivity and Quality of Crops.
Organized by Tigray Agriculture Research Institute.
7-8 June, 2019
Mekelle, Tigray

One major challenge holding back productivity in Ethiopia is decline in soil fertility. The current crop production system is characterized by continued nutrient mining, not only through crop harvests but also soil erosion, with very low return of the major nutrients back into the system. Moreover, nutrient balances for many cropping systems in the country are still negative, indicating that farmers are mining their soils, resulting in declining yields and contributing to food insecurity. Thus, deficiencies of macro- and micro nutrients are diminishing the production potential of rainfed and irrigated agriculture.

On the other hand, intensification of agricultural production through efficient use of organic and inorganic inputs is required to meet the food needs of the ever-growing population. The amount of fertilizer applied in Ethiopia has been one of the lowest in SSA, resulting in yields of major cereals averaging 1.8 t ha^{-1}, compared to the global average of beyond 3 t ha^{-1}. Recognizing the challenges, there is an increasing investment in importing chemical fertilizers, which reached from about 400,000 metric ton in 2014 to about 1.2 million metric ton in 2018. Moreover, Ethiopian cropping systems hugely vary from region to region, even within very short distances, due to differences in altitude, soil type, rainfall amount and distribution, food culture and access to resources and markets. This variability iscommonly reflected in the type, combination and amount of fertilizers required to improve crop productivity and minimize nutrient mining of agricultural landscapes.

There have been several country-wide efforts by various national and international research institutes to map the soils and develop fertilizer recommendations in Ethiopia. Ethiosis led by the Agricultural Transformation Agency (ATA) through its countrywide project, embarked on an ambitious plan to map the country's soil fertility status and compile in-depth soil fertility information, which could be used to inform development partners and policy makers in soil fertility status of the country and developed recommendation domains on nutrient requirements of the different regions, Woreda and Kebeles. The Ethiopian National and Regional research institutions have been also engaged in validating the recommendations and fine-tuning the fertilizer recommendations. In 2017 and 2018, the Ministry of Agriculture has also embarked on developing a revised soils strategy in consultation with national and international partners. The revised strategy considers integrated soil fertility management (ISFM) as a pathway for poverty reduction and resilience of rural livelihoods. All these various efforts have contributed to revitalize the soil health and fertility program of the country.

A recent review of soil and fertilizer research in Ethiopia (Tamene et al 2017) https://cgspace.cgiar.org/handle/10568/82996 showed that: (i) the productivity of major crops has increased steadily over the last two decades. Maize yield, for example, has increased from about 1.7 t ha^{-1} in 1993 to the current 3.4 t ha^{-1}. The biggest increase in yield for other crops such as wheat, barley and sorghum has also occurred during this last decade. (ii) Yield increase is strongly correlated with increased use of mineral fertilizers, particularly nitrogen and phosphorus. (iii) Limited response of crops to fertilizer inputs and investments could be largely explained by blanket application of nutrients, without targeting crop types, landscape position and drought regimes (Figures 1 and 2); (iv) A high degree of variability exists in crop response to nutrients and amendments in major cereal-growing areas in Ethiopia. This is mainly associated with variability in land-scape positions, agroecologies, soil characteristics and management practices. (v) Higher yield benefit was obtained when cereals were in rotation with N-fixing legumes such as faba beans and; (vi) in acidic soils, up to triple yield increase was recorded by application of lime. In general, these results indicated the need for ISFM using fertilizer application as an entry point.

Regardless of the efforts, farmers remain reluctant to invest in fertilizers as the farm return they have been getting is still very low. The effectiveness of matching fertilizer applications to soil fertility problems rests on the ability to identify production constraints, target specific niches and increase economic returns for fertilizer investments. Although most smallholder farmers appreciate the benefit of fertilizers, they rarely apply them at recommended rates and at the appropriate time because of unreliable returns, high cost of inorganic fertilizers, lack of supportive policy to access, and limited knowledge in efficient use of fertilizers. Ground-truthing research in various cropping systems of the country has shown that the crop response and economic benefits that farmers are getting from application of recommended fertilizer blends are still inconsistent and variable. In order to develop plausible fertilizer recommendation domains, it is essential to understand the diversity of the farming systems, landscapes and farmers' management practices and develop decision support tools that could guide matching of fertilizer types and rates against landscape conditions and farming typology.

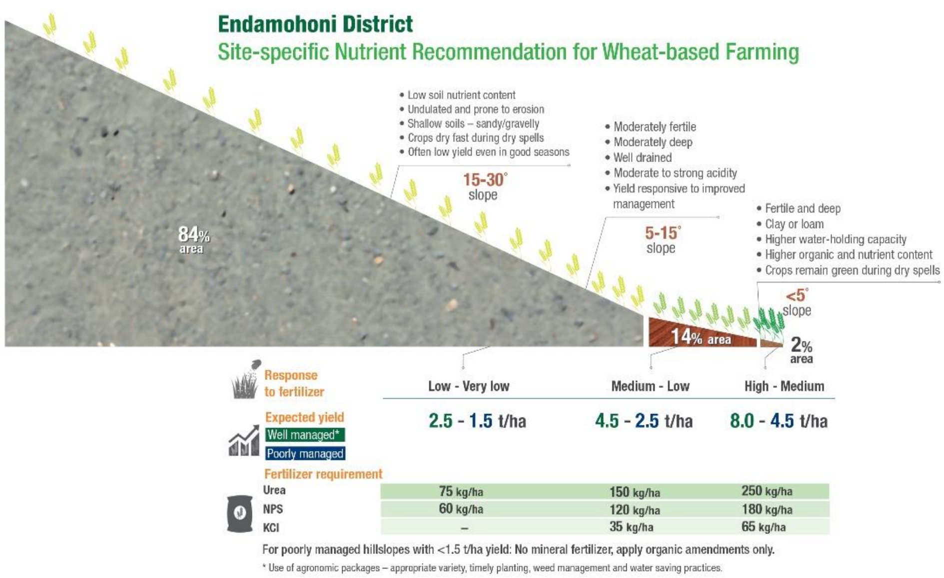

Figure 1. Decision guide for targeted, site-specific fertilizer recommendation for wheat-based farming systems in undulated Ethiopian highlands (Endamohoni, Tigray).

The International Crops Research Institute for the Semiarid tropics (ICRISAT) together with its national partners have been working on understanding the farming systems of Ethiopia https://www.researchgate.net/publication/296525932_The_Evolving_Farming_and_Pastoral_Landscapes_in_Ethiopia_A_Farming_System_Framework_for_Investment_Planning_and_Priority_Setting and developing tools and methods on how these differing farming systems, agroecologies and landscapes are best targeted by the appropriate type and amount of fertilizers.

In an ongoing joint initiative among ICRISAT, GIZ-ISFM+ and AfricaRISING, which has tested various combinations of fertilizers across farming systems, agroecologies, landscape positions, soil types in about 1000+ on-farm experiments, it came up with a draft site-specific decision guide, which would enhance crop yield, reduce input costs and enhance improved resources management at landscape scales. We have developed farmer friendly decision support guides (Version 1) (Figures 1 and 2) considering crop response to fertilizer applications across farming systems, agroecologies and landscape positions, which have been validated at pilot scales in four differing locations of wheat- and sorghum-based farming systems. Targeting fertilizer types and rates based on these decision support guides was found to increase crop yield by a range of 40–200%, while substantially decreasing production costs.

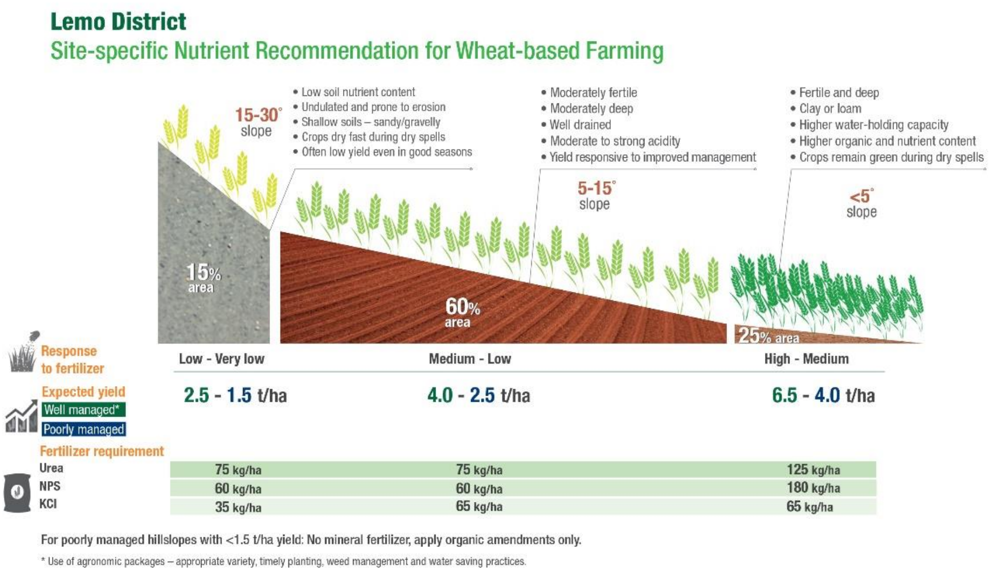

Figure 2. Decision guide for targeted, site-specific fertilizer recommendation for wheat-based farming systems in relatively flat Ethiopian mid-highlands (Lemo, Hadya Zone, SNNPR)

However, given the fact that these validations were done under researcher-managed on-farm conditions, the effectiveness of these guides under farmer management and local decisions may vary. The implication of this research is as follows.

1. It is important that extension agents and development partners appreciate landscape diversity, whereby there is almost certainly a reduced crop response with increasing slope and landscape position.

2. These findings provoked discussion on the current knowledge that soil-test based fertilizer recommendation be institutionalized. This has been also the backbone of Ethiosis maps. On the other hand, our work showed that depleted, shallow soils are not necessarily giving the highest response to fertilizer application.
3. The proxy indicators of landscape position, slope, soil depth and soil type as a means to prioritize fertilizer application are easy to observe and apply by less skilled extension officers and farmers
4. Given the high altitudes, undulated landscapes and dry environments of the Tigray region, this tool would be extremely useful to improve crop responses to fertilizer application, reduce input costs and improve overall system productivity. The crop-fertilizer response gradient may change in wet climates or years with high rainfall amount, which could be considered extreme events in the Ethiopian highlands.

5. The EthioSIS groundbreaking work in soils research in Ethiopia can be significantly improved by overlaying the above stated parameters to fine tune fertilizer recommendation and to reduce on-farm inputs costs significantly.

However, it is well recognized that mineral fertilizers alone cannot solve the problem. It is necessary to invest in sound and effective soil fertility management technologies (integrated nutrient management, microdosing, improved manure management, intercropping systems, integration of multipurpose legumes, reduced or no tillage practices, improved fallows, etc.) and empowering farmers with these technologies. This also implies the need for an integrated nutrient management plan considering the most limiting nutrients across various management and agroclimatic scenarios of the Ethiopian highlands.

Acknowledgement

This research has been conducted by the financial support of AfricaRISING, FTF-USAID and GIZ-ISFM programmes.

Invited Paper 2

Critical Nutrient Level (CNL) Approach for Nutrient Deficiency Diagnosis and Targeting Fertilizer Recommendation

Selamyihun Kidanu (PhD)
OCP S.A, Addis Ababa, Ethiopia

Correspondence: selamyihunkidane@gmail.com

Invited paper delivered at the National Workshop on Blend Fertilizer to Enhance Productivity and Quality of Crops.
Organized by Tigray Agriculture Research Institute
7-8 June, 2019
Mekelle, Tigray

Background on principle of crop nutrition

Low of the Minimum (Liebig, 1843): crop yields are proportional to the amount of the most limiting nutrient. Plant nutrients have specific and essential roles in crop metabolism. They cannot replace each other and lack of any one essential nutrient will limit crop growth. It is therefore essential to focus on a balanced nutrition of all plant nutrients. Therefore we need mineral fertilizers to replace nutrients removed with the harvest and to fulfil the growing demand for food and feed. Good crop nutrition enables increased water efficiencies. Sub-optimum crop nutrition tends to drive over-consumption of water while optimized crop nutrition improves water use efficiency. However, application of fertilizer should be integrated with supply of crop residue and organic fertilizers. Fertilizer consumption pattern and key mineral fertilizers in the world are indicated in Figure 1 and Figure 2. General fertilizer types can be complex multinutrient fertilizers which are used in horticulture, compound fertilizers having mixing single nutrient fertilizer (slurry or granulated product) and bulk blend fertilizers (customized balance by adjusting fertilizer inputs to crop requirements. Which product to use depend on the cost of the fertilizer and the cost of products decreased, respectively.

Approximately 60–80 % of the farm income is obtained at the expense of soil nutrient depletion in Ethiopia. National averages nutrient balances is estimated at -41 kg N, -6 kg P and -26 kg K per ha per year. Greater than 80% of agricultural lands have undulating topography, with up to 60 percent slope. There is hyper-local variability in soil, water and land characteristics. Ethiopia has the potential to double its current agricultural production through yield increase and industrialization. Rapid, accurate and compelling fertilizer recommendations for farmers, researchers and policymakers are required.

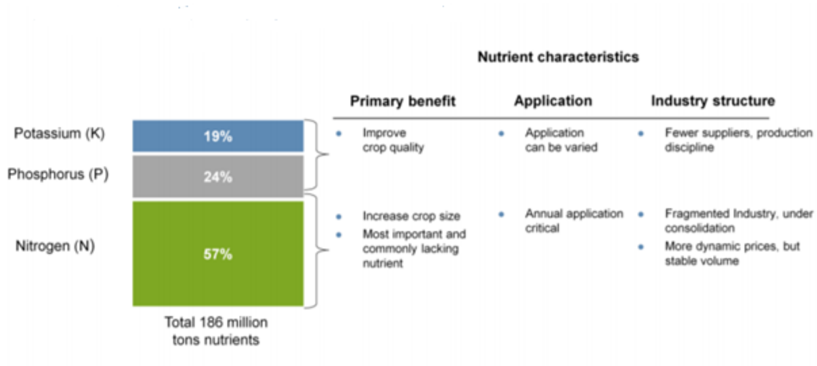

Figure 1. Fertilizer consumption pattern (Source: IFA 2018)

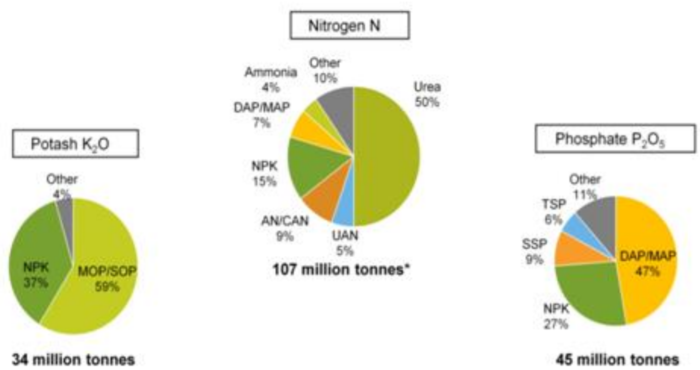

Figure 2 Key fertilizer production (Source: IFA 2016).

Approach for localizing soil and plant nutrient status/critical levels: Office Cherifien des Phosphates (OCP) experience in Ethiopia

Office Cherifien des Phosphates (OCP) is developing fertilizer recommendations based on soil and plant nutrient status/critical levels for sugar cane, coffee and problematic soil (soil salinity and acidity).

Sugar cane

Sugarcane is the most important industrial crop in Ethiopia (around 100,000 hectares). The annual production capacity is about 0.37 Million tones per year, though the national demand is above 0.65 Million tones. Per capita annual sugar consumption is 7 kg while the world average is 21 kg. Sugar Corporation is working to close these wide gaps and realize sugar export potential of the country.

About 1.5 million ha of fertile valley bottom soils are affected by salinity. The problem is increasing in connection with expansion of irrigation owing to poor on farm water management. Soil salinity is a major constraint in newly developed sugar states (90000 ha). Characterizing and mapping salt affected sugar cane growing soils is entry point to develop reclamation plan. Understanding the expected root zone salt balance under various crop rotations is equally important in planning the best cropping sequences during and after reclamation. Joint project has been developed to address the above issues through long term field experimentation in partnership with Sugar Corporation (SC), Haramaya University (HU), Hawassa University (HU), Morocco Polytechinic University (MPU), OCP, involving five PhD and six MSc students. Sugarcane productivity declined at rate of eleven tons/ha/decade between 1955 and 2016 at Wonji. However, global benchmarks reached yield plateau or increased sustainably with time. The OCP's proposal for intervention areas and the approaches and workflow for making crop and site specific fertilizer recommendation are indicated in Figure 3 and Figure 4.

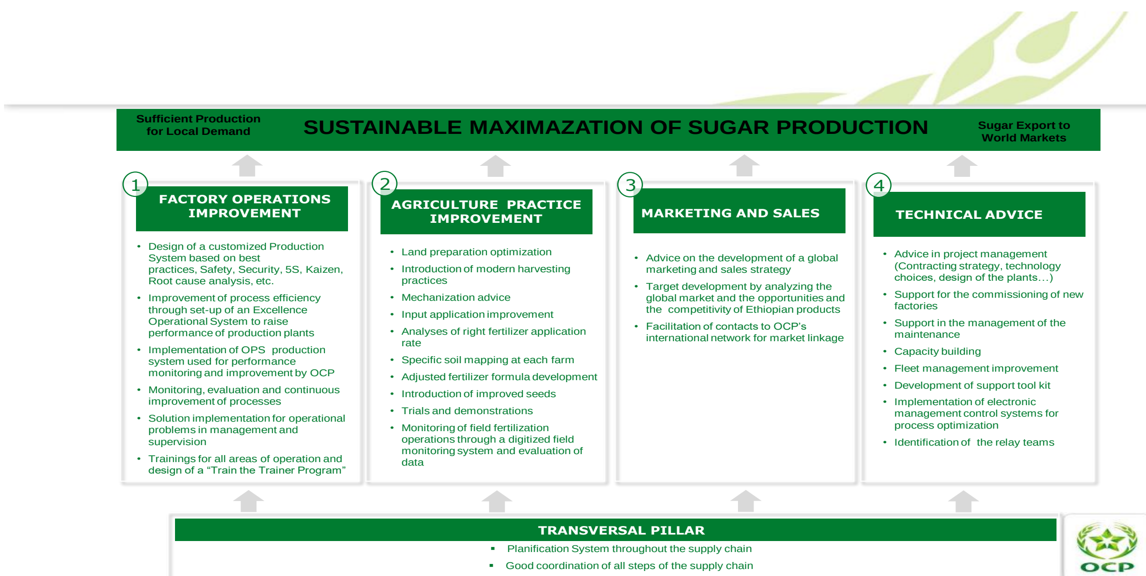

Figure 3. proposal for intervention areas and the approaches

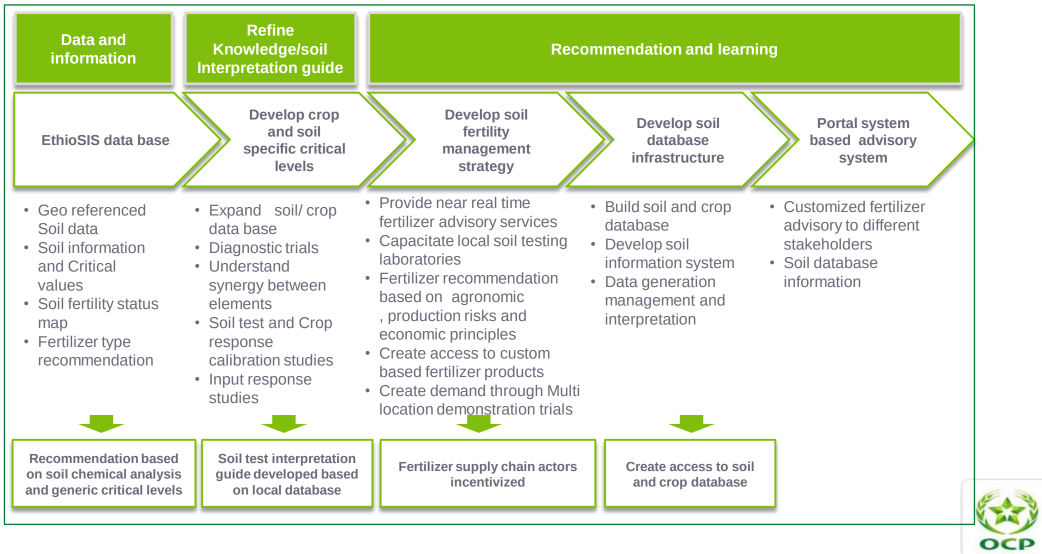

Figure 4. Workflow for making crop and site specific fertilizer recommendation

Coffee

Coffee is an important export crop. There is no dedicated fertilizer formula for coffee. Though, coffee productivity is below 0.5 t ha^{-1}. The OCP Ethio-AgriCEFT is intervening to improve productivity of coffee with the objective of assessing soil and crop and nutrient requirement, develop fertilizer formula dedicated to coffee Arabic and establish fertilizer scheduling and method of application.

Fertilizer recommendation for acidic soils

Seventy eight percent of agricultural lands in the Ethiopian highlands (>1800 masl) are covered by acidic soils with pH less than 6. It is in increasing race due to high rainfall and continuous farming activities on unsuitable hills and mountains. Acid soils geographically overlap with major cereal crop production belts of the country. Despite long history of research on cropping of acid soils in Ethiopia, little of acid soils has been limed nor have acidity tolerant cultivars been developed. Soil acidity poses significant economic loss through unachieved crop yield and wasted investment on fertilizer. Lime when combined with other input gives high and profitable yields for maize, tef and barley (Webeshet et al 2017 and Tadele et al 2013). Other study also indicated liming increases fertilizer efficiency and decreases soil acidity (Fertilizer Technology

Research Centre, 2009). Hence the possible strategy to alleviate the problem of soil acidity can be development of pathways that take full account of agro ecological diversity and promote balanced fertilisation program. Without the use of lime, fertilizers will increasingly acidify the soil until eventually crops will fail completely.

Conclusion

Finally, it can be concluded for successful fertilizer recommendation focus on value addition is important. Besides, plot level research should be connected with landscape issues. Building research capacity on big data analytics/capturing diversity/ and join hands and heads (inter institutional collaboration) targeting skill and knowledge transfer are vital. However, what farmers say matters most!!

Technical Papers

Evaluation of Blended NPSZn Fertilizer with Adjusted Nitrogen on Yield and Yield Components of Bread Wheat Grown on Vertisols and Cambisols under Rain-fed Condition at Mesanu in Hintalo-Wajerat and Shibta in Enderta Woredas, Tigray

Fisseha Hadgu*, Hagos Brhane, Sofonyas Dargie
Tsigabu Mehari, Aklil Gebremedhin, Lijalem Gebre-egziabher and Molla Haddis

Tigray Agricultural Research Institute, Mekelle Soil Research Center, P. O. Box 1070, Mekelle, Ethiopia

*Correspondence: habenfhb@gmail.com

Abstract

Field experiments were conducted with the objective of evaluating the effects of blended Nitogen, Phosphorus, Sulfur, Zinc (NPSZn) fertilizer rates adjusted with N on yield and yield components of bread wheat (Mekelle 3) grown on Vertisols of Mesanu in Hintalo-Wajerat and on Vertisols and Cambisols at Shibta in Enderta WoredaWoredas of Tigray during the main rainy seasons of 2017 and 2018. The experiments were carried out on farmers' fields in two sites at each location with three replications using randomized complete block design (RCBD), comprised of 8 treatments [0, 50, 100, 150, 200, 300 kg/ha NPSZn (adjusted with N to 64kg/ha) and recommended NP (64kg/ha N and 45 kg P_2O_5/ha)]. Composite soil samples were also initially collected from 0-20 cm depth of the fields and analyzed to determine major soil characteristics. The blended fertilizer rates were applied at the time of sowing while N was applied in the form of urea splitted into two applications. Phosphorus in the form of triple super phosphate (TSP) was also applied at planting time. Spike length, plant height, straw yield, grain yield data were collected and harvest index (HI) calculated. Crop data were analyzed using Statistix10 software program. Application of different rates of NPSZn fertilizers for two seasons significantly ($P \le 0.05$) and positively influenced most of the crop parameters tested. Significant differences ($P \le 0.05$) were observed on plant height, spike length, straw yield and grain yield whereas the differences were not significant for HI. Combined analysis of the two seasons' data showed highest biological parametrs at the rates of 300 kg NPSZn/ha blended adjusted with 25 urea/ha for Hintalo-Wajerat Vertisols and Enderta Cambisols and higest results were obtained at 250 kg/ha blended adjusted with 42 urea/ha for Enderta Vertisols. Partial budget analysis showed highest and profitable yield at 200 kg NPSZn/ha adjusted with 62 urea/ha for Mesanu in Hintalo Wajerat and at the rates of 50 NPSZn/ha adjusted with 115 urea/ha and 100 kg NPSZn/ha adjusted with 100 urea/ha for Vertisols and Cambisols at Shibta in Enderta, respectively for wheat. These profitable rates could be recommended for the respective soil types of the experimental areas and other areas with same soil type and agro-ecologies in Tigray.

Keywords: Cambisols, Vertisols, NPSZn fertilizer, wheat, soil characteristics

Introduction

Poor soil fertility and extreme exhaustion of plant nutrients from the soil are the major factors limiting crop production in different agro-ecological zones of Tigray. Nutrient mining due to sub optimal fertilizer use coupled with agronomically unblended fertilizer uses have favored the emergence of multi nutrient deficiency in Ethiopian soils (Asgelil et al 2007; Abyie et al 2003) which in part explain fertilizer factor productivity decline and stagnant crop productivity conditions encountered despite continued use of blanket recommendations.

Among the key strategies that were identified to help increase agricultural production and productivity in Growth and Transformation Plan I (GTP I) period was the soil fertility mapping of the country's agricultural lands. The soil fertility status and fertilizer recommendation atlas of TigrayNational RegionalState (TNRS) was completed in the year 2014 and published by Ministry of Agriculture (MOA) and Ethiopian Agricultural Transformation Agency (ATA) (2014) as part of the strategy. The necessity to transform agricultural sector with respect to soil fertility requires application of proper amounts of blended fertilizers for different crops.

Seven soil nutrients (N, P, K, S, Fe, Zn and B) were found to be deficient in the soils of Tigray Region (MoA and ATA 2014). Blended fertilizer types containing N, P, S, B, Fe and Zn in blended form have been recommended to solve site specific nutrient deficiencies and thereby increase crop production and productivity. The recently recommended blended fertilizers for Tigray Region by MOA and ATA were NPS, NPSB, NPSZn, NPSZnB, NPSFeZn and NPSFeZnB. Though K was part of the previous blend fertilizer, recently it was suggested to be applied based on soil test result. Among these fertilizer types, NPSZn (17.7 N – 35.3 P_2O_5 + 6.5S + 2.5 Zn) was recommended for Mesanu in HintaloWajerat Woreda and for Shibta in Enderta Woreda.

Experiments on blended fertilizers were carried out for the last few years in Tigray. However, in most of the study sites there were no significant differences among the different blended fertilizers as compared with the conventional N and P recommendations. The probable reasons could be (i) Blends were compared to each other, (ii) The formulation NPSZn contains insufficient amount of N.

Although blended NPSZn fertilizer was one of the major blended fertilizers identified for the WoredaWoredas, optimum rates of the fertilizer for different crops, agro ecologies and soil types were not yet determined. Besides, verifying the soil fertility status and fertilizer recommendation atlas for wheat grown in these WoredaWoredas on different soil types was urgently needed to increase wheat yield grown in the region. Therefore, these experiments were conducted to evaluate NPSZn fertilizer on yield, yield component of bread wheat in Hintalo-Wajerat and Enderta on wheat during 2017 and 2018 cropping seasons under rain-fed conditions.

Materials and Methods

Description the study Area

Two experiments (at two sites) were carried out on Vertisols of Hintalo Wajerat (Mesanu Village) in 2018 main cropping season. Other four experiments were also conducted on two different soil types (Vertisols and Cambisols) at Shibta in Enderta for two seasons (2017 and 2018 main cropping seasons) (Figure 1).

Figure 1. Location map of the study areas

The maximum and minimum temperatures, 22.9 and 10.3^{0} C respectively, for the year 2018 are taken from Adi-Gudom meteorological station. ,. The mean annual rainfall of Mesanu calculated from 2008 to 2017 was 474.0 mm taken from Adi-Gudom. The mean annual rainfall of Shibta, calculated from meteorological data taken from Alula-Aba-Nega Air port for the period 2008 to 2017, was 335.2 mm. The annual rainfall of the Shibta in 2017 was 440.5mm of which 359.5 mm was calculated for the period of June to September.

Experimental design and treatment

The experiments conducted in the WoredaWoredas were laid out in RCBD with three replications at two sites at Mesanu in Hintalo-Wajerat WoredaWoreda for one season and at Shibta, at two sites with different soil types, for two cropping seasons. Plot sizes of each plot in the experimental sites were 3 m by 3 m. The spacing between plots and replications were 50 and 100 cm, respectively. The spacing between wheat plant rows was 20 cm. The experiments had eight treatments [0, 50, 100, 150, 200, 250, 300, NPSZn kg ha^{-1}) adjusted with N to the recommended level as well as N and P fertilizers (64 kg Nha^{-1}, 46 kg P_2O_5 ha ^{1})]. Blended fertilizer treatments including 0, 50, 100, 150, 200, 250 300 NPSZN kg/ha as well as recommended rate of N and P were applied at the time of sowing. The treatments with the blended rates were supplied with adjusted N in the form of urea. Phosphorus in the form of TSP was applied at the rate of 100 kg /ha to all experimental plots.

Representative composite soil samples from each field were taken before planting following the standard soil sampling procedure. Each composite soil sample was used for selected physico-chemical analysis [soil texture, soil reaction (pH), electrical conductivity (EC) , organic carbon (OC), cation exchange capacity (CEC), total N, and Olsen P]. Particle size distribution was determined using the Bouyoucos hydrometer method (Bouyoucos, 1962). The pH of the soil was measured in the supernatant suspension of a 1: 2.5 soil to water ratio using a pH meter (Rhoades, 1982). Walkely and Black (1934) used for determination of organic carbon. Total N was determined using the Kjeldahl method as described by (Bremner and Mulvaney 1982). Available P was determined following the Olsen method (Olsen et al 1954) using ascorbic acid as reducing agent. Cation exchange capacity was determined by ammonium acetate method.

Data collection

Plant height, spike length, grain yield and straw yield were collected and HI calculated from yield and biomass.

Data analysis

Data were subjected to statistical analysis. Analysis of variance (ANOVA) was carried out using Statistix10 software program. Significant difference between and among treatment means was assessed using the least significant difference (LSD) at 0.05 level of probability (Gomez and

Gomez 1984). Partial budget analysis was calculated to determine the more profitable blended fertilizer rates adjusted with N fertilizer.

Result and Discussion

Soil properties before planting

The results of the lab analysis are presented in Table1.The textural classes of the soils were Clay for Hintalo-Wajerat and Shibta Vertisols andLoam for Shibta Cambisols. The EC in the four sites is low. The soil pH for Hintalo-Wajerat is mildly alkaline and neutral for the sites in Enderta. High CEC is recorded for Hintalo-Wajerat and Shibta Vertisols and moderate for Shibta Vertisols. Organic carbon content for the four sites is very low. All sites is very high for Hintalo-Wajerat Vertisols, high for Shibta Cambisols and moderate for Shibta Vertisols respectively.

Table 1. Some soil characteristics of experimental fields used for blended fertilizer experiments at Hintalo-Wajerat and Enderta Woredas

Parameter	Hintalo (Site 1)	Hintalo (Site 2)	Hintalo (average)	Shibta (Vertisols)	Shibta (Cambisols)
pH_{water} (1:2.5)	7.34	7.78	7.56	7.03	6.85
EC (ds/m)	0.22	0.23	0.225	0.07	0.23
OC (%)	1.06	1.03	1.045	1.32	0.76
Total N (%)	0.084	0.115	0.995	0.112	0.10
Olsen-P (mg kg^{-1})	23.62	28.99	26.305	10.48	21.08
CEC (cmol (+) kg^{-1} soil)	42.76	25.91	34.34	34.64	18.42
Sand (%)	18	28	23	40	46
Silt (%)	28	28	28	6	30
Clay (%	62	44	53	54	24
Textural class	Clay	Clay	Clay	Clay	Loam

Yield and yield components

Combined analysis of the data over two sites in each location showed significant differences (P< 0.05) in plant height, spike length, grain and straw yield. No significant difference was observed for HI at the three experimental locations (Tables 2, 3 and 4).

Although differences were not statistically significant highest plant height was recorded when 300 kg NPSZn/ha was applied showing 32.5% increment over the control. Grain and straw yield analysis showed statistically significant differences (P< 0.05) and higher grain and straw yields were obtained at the rate of 300 kg NPSZn/ha. However, the straw and grain yield differences were not significant for the treatments above 200 kg NPSZn/ha (Table 2) in Hintalo-Wajerat .

Table 2. Effect of blended fertilizer on yield and and yield componentsof wheat grown at Mesanu in Hintalo-Wajerat Woreda combined over sites (site 1 and site 2) in 2018.

Trteatment*	Ph (cm	SL (cm)	GY (kg ha^{-1})	SY (kg ha^{-1})	HI
0 kg	53.97e	5.72c	1268.1d	1663.5d	0.43
50 NPSZn	59.13d	6.379b	1725.0cd	2366.0c	0.418
100 NPSZn	62.70cd	6.67ab	1847.2c	2458.3c	0.431
150 NPSZn	66.10bc	6.70ab	1933.3bc	2497.2c	0.438
200 NPSZn	66.67abc	6.89ab	2463.5ab	3318.4ab	0.43
250 NPSZn	70.53ab	7.17a	2647.2a	3375.0a	0.442
300 NPSZn	71.50a	7.08a	2855.6a	3916.7a	0.424
R NP	66.07bc	6.83ab	2058.3bc	2655.6bc	0.443
LSD	5.1005	0.6088	534.52	700.06	NS
CV	6.68	7.71	21.52	21.28	4.44
P value	0	0.0012	0	0	0.3305
Site 1	61.37b	6.5	1887.3b	2314.5b	0.448
Site 2	67.80a	6.86	2312.2a	3248.2a	0.416
LSD	2.4396	Ns	181.14	161.13	0.0207
CV	4.71	11.14	10.76	7.23	5.98
P value	0.0019	0.1687	0.0029	0.0001	0.0123

* : LSD = Least significant difference, CV = Coefficient of variation,Ph = Plant height, SL = Spike length, GY = Grain yield, SY = Straw yield, RNP = Recommended Nitrogen and phosphorus and HI = Harvest index

Highest plant height was recorded when 250 kg NPSZn/ha was applied showing 27.5% increment over the control but the differences were not statistically significant with that of the other NPSZn treatments for Vertisols at Shibta. Higher spike length was observed at 250 kg NPSZn/ha and higher grain and straw yields were obtained at the rate of 300 kg NPSZn/ha. However, spike length and grain yield differences were not significant for the treatments above 50 kg NPSZn/ha on Vertisols at Shibta (Table 3). Highest plant height, grain and straw yield were recorded when 300 kg NPSZn/ha was applied for Cambisols at Shibta (Table 4).

Partial budget analysis

Partial budget analysis on grain and straw yields showed >100% marginal rate of return for the treatments 50 to 300 kg NPSZn/ha with adjusted N fertilizer as well as recommended N and P on Vetisols in Hitalowajerat (Table 5). Similar to our result, Abebaw Tadele Alem and Hirpa Legese (2018) reported a significant and profitable effect of blended fertilizer (NPSZn) on wheat at the rate of 200 kg/ha at ArjoDidessa (Western Ethiopia). For durum wheat at DebreZeit, Bizuwork Tafes Desta (2018) concluded that combined application of 100 kg NPSB and 92 kg N/ha gave economically profitable results on Vertisols.

Partial budget analysis on grain and straw yields showed highest marginal rate of returns at the rates of 250 kg NPSZn/ha with adjusted N fertilizer onVertisols at Shibta in Enderta (Table 6). Partial budget analysis on grain and straw yields showed highest marginal rate of returns at the rates of 100 kg NPSZn/ha with adjusted N fertilizer for wheat grown on Cambisols in the area (Table 7).

Table 3. Effect of blended fertilizers on yield and yield componentsof wheat grown on Vertisols at Shibta in Enderta Woreda combined over years (2017 and 2018).

Trteatment	PL (cm)	SL (cm)	GY (kg ha^{-1})	SY (kg ha^{-1})	HI
0 kg	65.80d	6.07c	1186.1c	2205.6f	0.346
50 NPSZn	75.70c	7.15ab	1911.1ab	3516.7de	0.349
100 NPSZn	75.07c	6.87b	1972.2ab	3613.9cde	0.350
150 NPSZn	78.50bc	7.12ab	2069.4ab	4116.7bcd	0.331
200 NPSZn	77.90bc	6.98ab	2130.6ab	4252.8abc	0.333
250 NPSZn	83.87a	7.33a	2377.8a	4741.7ab	0.332
300 NPSZn	80.43ab	7.17ab	2344.4a	4861.1a	0.322
RNP	75.70c	7.10ab	1747.2c	3455.6e	0.333
LSD	4.5309	0.4221	491.46	655.51	NS
CV	5.0	5.12	21.12	14.41	7.77
P value	0.0000	0.0001	0.0009	0.0000	0.5236
Year 1	78.3	7.43a	2258.3	4352.1	0.342
Year 2	74.94	6.52b	1676.4	3338.9	0.332
LSD	NS	0.1788	NS	NS	NS
CV	8.06	3.20	50.46	33.55	16.48
P value	0.1326	0.0001	0.1121	0.0530	0.5950
P value of Year*Trt.	0.0211	0.0975	0.4438	0.1185	0.3178

* : LSD = Least significant difference, CV = Coefficient of variation,PL = Plant height, SL = Spike length, GY = Grain yield, SY = Straw yield, Trt = treatment, RNP = Recommended Nitrogen and phosphorus and HI = Harvest index

Table 4. Effect of blended on yield and growth parameters of wheat grown at Cambisols at Shibta in Enderta Woreda combined over the years (2017 and 2018).

Trteatment	PL (cm)	SL (cm)	GY (kg ha^{-1})	SY (kg ha^{-1})	HI
0 kg	74.27c	6.70d	1505.60c	2697.2e	0.357
50 NPSZn	78.30b	6.92cd	2075.00c	4000.00d	0.340
100 NPSZn	78.90b	7.03bcd	2233.3abc	4375.00cd	0.336
150 NPSZn	81.07ab	7.25abc	2130.60bc	4705.6bc	0.328
200 NPSZn	81.67ab	7.05bcd	2500.00 ab	5180.6ab	0.323
250 NPSZn	84.00a	7.50a	2313.90abc	4672.2c	0.317
300 NPSZn	82.90a	7.23abc	2563.90a	5494.4a	0.315
RNP	81.23ab	7.40ab	1986.10c	4275.0cd	0.310
LSD	3.9798	0.3942	405.42	507.70	NS
CV	4.19	4.67	15.84	9.70	9.15
P value	0.0009	0.0058	0.0004	0.0000	0.1679
Year 1	78.30b	7.43	2258.3	4352.1	0.3415
Year 2	82.28A	6.84	2068.8	4497.9	0.3151
LSD	2.9132	0.3942	NS	NS	NS
CV	3.9798	5.19	47.54	22.79	17.64
P value	0.0192	0.0054	0.5579	0.6427	0.1887
P value of Year*Trt.	0.3260	0.7937	0.6148	0.5490	0.4021

* : LSD = Least significant difference, CV = Coefficient of variation,PL = Plant height, SL = Spike length, GY = Grain yield, SY = Straw yield, Trt = treatment, RNP = Recommended Nitrogen and phosphorus and HI = Harvest index.

Table 5. Partial budget analysis for Hitalowajerat(combined over sites)

Treatment (NPSZn RNP)*	Adjusted GY (kg/ha)	Adjusted SY (kg/ha)	Total fertilizer (ETB)	Fertilizer, transport & application cost	TVC)	Grain revenue	Straw revenue	Total revenue	Net revenue [TR-TVC]	MRR (ratio)	MRR (%)
0	1355.0	2427.5	0.0	0.0	0.0	18970.6	7767.9	26738.5	26738.5	-	-
50	1867.5	3600.0	2316.8	254.8	2571.7	26145.0	11520.0	37665.0	35093.3	3.2	324.9
100	2010.0	3937.5	2791.6	301.0	3092.6	28139.6	12600.0	40739.6	37647.0	4.9	490.2
150	1917.5	4235.0	3266.4	347.1	3613.5	26845.6	13552.1	40397.7	36784.2	D	D
RNP	1787.5	3846.6	3695.1	358.7	4053.8	25024.9	12309.1	37334.0	33280.2	D	D
200	2250.0	4662.5	3741.1	393.3	4134.4	31500.0	14920.1	46420.1	42285.7	4.5	
250	2082.5	4205.0	4215.9	439.4	4655.3	29155.1	13455.9	42611.1	37955.8	D	D
300	2307.5	4945.0	4690.8	485.6	5176.3	32305.1	15823.9	48129.0	42952.7	0.6	64.0

* = RNP = Recommended N & P fertilizers, GY = Grain yield, SY = Straw yield, TVC = Total variable cost.

Table 6.Partial budget analysis for EndertaVerttisols (combined over two years)

Treatment (NPSZn RNP)	Adjusted GY	Adjusted SY	Total fertilizer Cost	Fertilizer, transport & application cost	TVC	Grain revenue	Straw revenue	Total revenue	Net revenue (TR-TVC)	MRR (ratio)	MRR (%)
0	1067.5	1985.0	0.0	0.0	0.0	14944.9	6352.1	21297.0	21297.0		
50	1720.0	3165.0	2316.8	254.8	2571.7	24079.9	10128.1	34208.0	31636.3	4.0	402.0
100	1775.0	3252.5	2791.6	301.0	3092.6	24849.7	10408.0	35257.8	32165.2	1.0	101.5
150	1862.5	3705.0	3266.4	347.1	3613.5	26074.4	11856.1	37930.5	34317.1	4.1	413.1
RNP	1572.5	3110.0	3695.1	358.7	4053.8	22014.7	9952.1	31966.9	27913.1	D	D
200	1917.5	3827.5	3741.1	393.3	4134.4	26845.6	12248.1	39093.6	34959.2	1.2	123.3
250	2140.0	4267.5	4215.9	439.4	4655.3	29960.3	13656.1	43616.4	38961.1	7.7	768.3
300	2110.0	4375.0	4690.8	485.6	5176.3	29539.4	14000.0	43539.4	38363.1	D	D

* GY = Grain yield; SY = straw yield; TVC = Total variable cost, MRR = Marginal rate of return

Table 7.Partial budget analysis for EndertaCambisols (combined over two years)

Treatment (NPSZn RNP)*	Adjusted GY	Adjusted SY	Total fertilizer Cost	Fertilizer transport & application cost	TVC)	Grain revenue	Straw revenue	Total revenue	Net revenue [TR-TVC]	MRR (ratio)	MRR (%)
0	1355.0	2427.5	0.0	0.0	0.0	18970.6	7767.9	26738.5	26738.5	-	-
50	1867.5	3600.0	2316.8	254.8	2571.7	26145.0	11520.0	37665.0	35093.3	3.2	324.9
100	2010.0	3937.5	2791.6	301.0	3092.6	28139.6	12600.0	40739.6	37647.0	4.9	490.2
150	1917.5	4235.0	3266.4	347.1	3613.5	26845.6	13552.1	40397.7	36784.2	D	D
RNP	1787.5	3846.6	3695.1	358.7	4053.8	25024.9	12309.1	37334.0	33280.2	D	D
200	2250.0	4662.5	3741.1	393.3	4134.4	31500.0	14920.1	46420.1	42285.7	4.5	450
250	2082.5	4205.0	4215.9	439.4	4655.3	29155.1	13455.9	42611.1	37955.8	D	D
300	2307.5	4945.0	4690.8	485.6	5176.3	32305.1	15823.9	48129.0	42952.7	0.6	64.0

Conclusion and Recommendation

Biologically higher response due to the treatments were obtained for grain and straw yield, and plan height at the rates of 300 NPSZn and 25 urea kg/ha. However, there were no significant differences in grain and straw yields with the application of 200-300 NPSZn and 62-25 urea kg/ha. The highest marginal rate of return was observed at 200 NPSZn and kg/ha adjusted with 62 kg/ha urea for Hintalo-Wajerat Vertisols. This rate (200kg NPSZn/ha adjusted with 62 urea) can be recommended as better rate for wheat grown on Hintalo-Wajerat Vertisols. However, considering cost and yield, 50-300 kg/ha NPSZn with adjusted 115 - 25 kg/ha urea could be applied for wheat on Vertisols for areas having similar agro-ecology with that of Hintalo-Wajerat.

For Vertisols at Mesanu (Shibta), biologically higher responses were obtained at 250 kgNPSZn and 42 kg urea/ha. For Cammbisols at Godagudi (Shibta), biologically higher responses were obtained at 300 kgNPSZn and 25 kg urea/ha .However, there were no significant differences in grain yield when 200-300 NPSZn and 62-25 urea kg/ha were applied on Vertisols at Shibta. The rates starting from 50 up to 250 kg/ha NPSZn and 115-42 kg/ha urea can be recommended for Vertisols in Shibta. For the Cambisols at Shibta and areas with similar agro-ecology and soil type, starting from 100 kg/ha NPSZn adjusted with 100 kg urea/ha could be recommended as this rate is more profitable.

Acknowledgements

We would like to thank Mekelle Soil Research Center for its support in the implementation of this study by providing vehicles and for its financial sponsorship. We are also grateful to Mr. Girmay Hailu, Hagos W/Gebriel and other laboratory staff for their contribution in soil analysis at in the soil laboratory of Mekelle Soil Research Center.

References

Abebaw Tadele Alem and HirpaLegese (2018): Effects of fertilizer rate (blended) and sowing methods on yield of bread wheat (*Triticumaestivum*) and its economic profitability in Western Ethiopia. International Journal of Comprehensive Research in Biological Sciences,Volume -5; Issue -7; Pages: 1-14.

Analytical Software (2013): Statistix 10 User's Manual. Analytical Software, Tallahassee, FL.

ATA (Ethiopian Agricultural Transformation Agency) and MoA (Ministry of Agriculture), (2014): Soil Fertility Status and Fertilizer Recommendation Atlas for Tigray Regional State, Ethiopia.

BizuworkTafes Desta (2018): Growth, yield and grain quality of durum wheat.

(*Triticumturgidum*L.var. durum) as influenced by rates of blended NPSB and N Fertilizers at DebreZeit, Central Ethiopia. MSc. Thesis. Haramaya University.

Bouyoucos GJ (1962): Hydrometer method improved for making particle size analyses of soil. Agron. J., 53: 464-465.

Chapman HD (1965): Cation exchange capacity. Part II. In*:* Black CA, Evans DD, Ensminger JL, Clark FE, eds. Methods of soil analysis., Madison, WI, USA : ASA, p.891-901.

Charman PE and Roper MM (2007):Soil organic matter. In: Charman P.E., Murphy B.W., eds. Soils-their properties and management, 3rd edition. Melbourne, Australia: Oxford University Press, pp. 276-285.

CIMMYT(1988): From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico.

Cottenie A (1980): Soil and plant testing as a basis of fertilizer recommendations. FAO soil bulletin 38/2. Food and Agriculture Organization of the United Nations,Rome.

CSA(Central Statistical Agency)(2007):Ethiopianpopulation and housing census 2007.

CSA (Central Statistical Authority) (2014). Agricultural Sample Survey, 2013/2014 (2006 E.C.). Report on Area and Production for Major Crops: Private Peasant Holding'Meher' Season. Statistical Bulletin 532, CSA, Addis Ababa, Ethiopia.

Fageria NK, Baligar VC and Jones CA (2011): Growth and Mineral Nutrition of Field Crops. Third Edition.Taylor and Francis Group, LLC.,pp 235-256.Boca Raton.

Gomez and Gomez H (1984): Statistical analysis for agricultural research.John Willy and Sons Inc. pp.120-155.

Metson AJ **(**1961). Methods of chemical analysis for soil survey samples. *Newzealand*

*Department of Scientific and Industrial Research, Soil Bureau Bulletin.*pp. 168-175. In:

Hazelton, P.A, Murphy, B.W., eds. Interpreting soil test results: what do all the, numbers mean?.2nd Edition. Government Printer,Wellington, New Zealand, New South Wales (NSW) Department of Natural Resources, CSIRO Publishing, Collingwood, Australia.

Olsen SR, Cole CV, Wanatabe FS and Dean LA (1954):Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circular, 939.

Tekalign Tadese (1991): Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13.International Livestock Research Center for Africa, Addis Ababa.

Walkley A and IA Black (1934):An examination of the Degtjareff method for determining soil organic matter and proposed chromic acid titration method. Soil Science, 37: 29-38.

Effect of Blended NPSZnB Fertilizer with Adjusted N on Yield and Yield Component of Bread Wheat (*Tritcum aestivum*) in Hawzen Woreda of Tigray, Ethiopia

Bereket Haileselassie*, Hagos Brhane, Sofonyas Dargie, Fisseha Hadgu, Tsigabu Mehari, Gebremedhin Berhe, Aklil Gebremedhin and Daniel Berhe

Tigray Agricultural Research Institute, Mekelle Soil Research Center, P. O. Box 1070, Mekelle, Ethiopia

*Correspondence: berekethaileselassie08@gmail.com

Abstract

Field experiments arranged in Randomized Complete Block Design (RCBD) were conducted during 2017 and 2018 cropping seasons to evaluate the effect of blended NPSZnB fertilizer under adjusted nitrogen (N) fertilizer on yield and yield components of breadwheat (*Tritcum aestivum*) grown on Cambisols of Hawzien Woreda. The treatments were seven rates of NPSZnB (0, 50, 100, 150, 200, 250, 300, kg ha^{-1}) and one blanket recommended N and P fertilizers (64 kg Nha^{-1}, 46 kg P_2O_5 ha^{-1}). The N content in the blend fertilizer treatments were adjusted to 64 N ha^{-1} by urea top dressing. Highest grain and straw yields of bread wheat were recorded at the highest blended fertilizer rate (300 kg ha^{-1}) though the yields were statistically at par with application rate of 100 kg ha^{-1} for grain and 200 kg ha^{-1} for biomass and straw yield. The 200 kg ha^{-1} NPSZnB blended fertilizer adjusted with 28.6 kg N in the form of urea by top dressing was found to be economical both from biomass or grain and straw yields improvement perspective. Improvement in grain and straw yields are equally important to farmers. From a grain productivity improvement perspective, 100 kg ha^{-1} NPSZnB blended fertilizer with 46.3 kg N in the form of urea by top dressing had similar grain yield with previously recommended N and P rates. Hence, further research should be conducted on interaction effects of N and P with the other nutrients in the blend (S, Zn and B) to find optimum interaction levels and to indicate the nutrients that significantly contribute for improvement of wheat productivity in general and possibly for product quality in particular.

Keywords: Blended fertilizer, Hawzen, Bread wheat

Introduction

Bread wheat is an important crop which is grown in many areas globally than any other and provides a major share of the nutritional requirements for the growing world population (Shapiro 2009). Traditionally, bread wheat is used for making "dabo", "dabokolo","ganfo", "kinche" and other types of food in Ethiopia (Mathewos et al 2012). Besides, bread wheat straw is an integral component of livestock feed and commonly also used as a roof thatching material both in the rural and urban areas in Ethiopia (Seyoum and Zinash 1989).

Bread wheat yield in Ethiopia is low compared to other wheat producing countries in Africa and the world. Poor agronomic and soil management, inadequate level of technology generation and dissemination are the most significant constraints to increased bread wheat production in

Ethiopia. Low soil fertility followed by slow progress in developing bread wheat cultivars with durable resistance to disease, pests and weed are considered the most important constraints limiting bread wheat production in Ethiopia (Demeke and Di Marcantonio 2013).

In Tigray, poor soil fertility is also among the major crop production constraints in. Soil fertility map of Tigray was published by the Ministry of Agriculture (MoA) and Ethiopian Agricultural Transformation Agency (ATA) (MoA and ATA 2014). Accordingly, the soils of Hawzen Woreda wereidentified as low in soil organic carbon (OC) , total N, phosphorus (P), potassium (K), sulfur (S), boron (B) and zinc (Zn). Hence, fertilizer studies were conducted for consecutive two years to evaluate the effects of NPSZnB blended fertilizers under adjusted N level in the form of urea on yield and yield components of bread wheat.

Materials and Methods

On-farm field experiments were conducted in 2017 and 2018 growing seasons in Hawzen Woreda, Tigray, Ethiopia (Figure 1) to evaluate the response of bread wheat to blended NPSZnB fertilizer. Hawzen Woreda is located (Figure 1) in tepid to cool sub moist mountains plateau agro ecological zone (Anonymous 2000). Cambisols in Hawzen Woreda are one of the most degraded soils in the Tigray region which are believed to be very poor in soil organic matter (Bereket et al, 2014). Wheat is grown during the main season from June to September. The mean annual rainfall is 510 mm. The rainfall in 2017 and 2018 was 351 mm and 319 mmrespectively. The rainfall data was summarized from the nearest Woreda data (Hawzen Office of Agriculture and Rural Development, unpublished data). Annual mean maximum temperature is around 24^{o}C and mean minimum is around 7.7 ^{o}C according to LocClim 1.0 software (FAO 2002).

The field experiments consisting of eight treatments were laid out in RCBD with three replications at two sites per year during the croppingseasons of 2017 and 2018. The experiment was conducted in a plot size of 3 m by 3 m with spacing 1m, 0.5 m and 0.2 m between blocks, plots and plants, respectictively. The treatments consisted seven NPSZnB rates (0, 50, 100, 150, 200, 250, 300, kg ha^{-1}) and one blanket recommended N and P fertilizers (64 kg N ha^{-1}, 46 kg P_2O_5 ha^{-1}). The blended fertilizer was applied during planting. The N content in the blend fertilizer treatments were adjusted to 64 kg N ha^{-1} by urea top dress application.

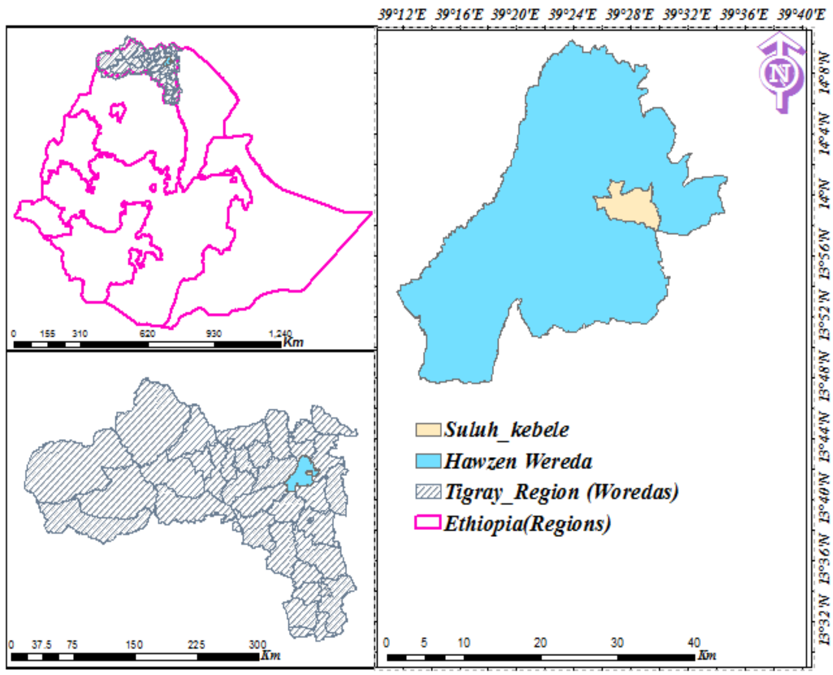

Figure1. Location map of the Hawzien Woreda, Tigray, Ethiopia

Representative composite soil samples from each field were taken before planting following the standard soil sampling procedure. Each composite soil samples were used to analyse selected physico-chemical parameters[particle size analysis , pH, electrical conductivity (EC), organic carbon (OC), cation echange capacity (CEC), total N and available P]. Particle size analysis was determined by hydrometer method (Day, 1965). Soil pH and EC were measured in 1:2.5 soil water suspensions (Jackson, 1967). Organic carbon content was determined by using modified Walkley and Black method (Jackson,1967) CEC exchange capacity by sodium acetate (NaOAc) extraction method by adjusting the pH to neutral (Chapman, 1965). Available P was estimated by Olsen method (Olsen et al, 1954) while total N was determined by Kjeldhal method (Bremner and Mulvaney ,1982).

Kakaba wheat variety was used as test crop. Agronomic data including straw and grain yields, plant height and spike length, were collected following standard procedures. The collected data were subjected to analysis of variance. Means were compared with Least Significant Difference (LSD) test at 5% level of probability. All analyses were performed with GenStat 14th edition (VSN 2011).

Results and Discussion

Selected physicochemical properties of the study sites

The soil textural classesof for all the study sites were sandy loam with a sand content from 60 to 82 % (Table 1). The pH of the soils of the study sites was slightly acidic in accordance with rating of Tekalign (1991). The soils of all the study sites were non-saline with an EC of < 2 dS m^{-1}. The soil OC content and total N were low (< 1.5%) and very low (< 0.1), respectively according to Tekalign (1991). The soil available P status of the three sites were high (Olsen-P > 10 mg kg^{-1}) while the remaining one site was very low (Olsen-P < 5 mg kg^{-1} soil) (Olsen 1954).The CEC of the soils ranged 4.45 to 10.06 which is considered as low (5-15 Cmol(+)kg^{-1} soil) according to Landon (2014). Deficiencies of S, Zn and B (MoA and ATA 2014) and Zn (Bereket et al 2018; Bereket 2018) were also reported low in the soils of Hawzen Woreda.

Table1. Selected physicochemical properties of surface (0-20 cm deep) fields for NPSZnB blend fertilization experiments, Hawzen Woreda, Tigray.

Soil parameter	Year I (2017)		Year II (2018)	
	Site1	Site2	Site3	Site4
pH-H_2O	6.73	6.025	6.56	6.08
EC, ms cm^{-1}	0.11	0.04	0.054	0.058
CEC Cmol(+)kg^{-1} soil	6.27	7.27	10.06	4.54
OC (%)	0.567	0.374	0.315	0.41
Total-N (%)	0.084	0.034	0.085	0.078
Olsen- P (mg kg^{-1})	11.5	4.45	12.89	11.10
Sand (%)	74	60	78	82
Silt (%)	16	26	10	6
Clay (%)	10	14	12	12
Textural class	SL	SL	SL	SL

Effects on growth parameters and yield of bread wheat

There was no interaction effect of year, site and the fertilizer treatments on growth, yields and harvest index of bread wheat (Table 2). The main effect of year significantly (P<0.01) affected spike length, grain yield and harvest index of wheat. This might be due to the weathervariability especially rain fall between the two years. There was significant difference between the sites for plant height, grain yield, straw yield and harvest index of bread wheat. The probable reason for the variability could be due to the combined soil characteristics effects of the sites (Table 1). Highest grain yield and significant (P<0.01) highest biomass and straw yield of bread wheat were attained at the blended NPSZnB fertilizer rate of 300 kg ha^{-1}. The recorded grain yield increment at this rate over control and recommended N and P were 58% and 11.7%, while the recorded straw yield increment were 87% and 16%, respectively. Though, the recorded increments at this rate were statistically at par with NPSZnB fertilizer rate of 100 kg ha^{-1} for grain and 200kg ha^{-1} for straw indicating application at these rates improve productivity of wheat both from human and livestock feed consumption perspective. Improvement in grain and straw yields are equally important to farmers. While comparing with the previous recommended N and P fertilizer rates, 100 kg ha^{-1} NPSZnB with 46.3 kg N in the form of urea by top dressing was statistically similar with the recommended rate for grain yield while 200 kg ha^{-1} NPSZnB with 28.6 kg N in the form of urea by top dressing was superior for biomass and straw yield than the recommended rate. This indicated that the combined contribution of S, Zn and B or either of the nutrients in the blend fertilizer had also improved productivity of bread wheat. Because N fertilizer was adjusted to 64 kg ha^{-1} in all the blend fertilizer treatments, and three of the four sites had also P soil level in the optimum soil rating and the blend fertilizer treatments were also compared with recommended P (Figure 1; Table 1). Sulfur, Zn, and B (MoA and ATA 2014) and Zn (Bereket et al 2018; Bereket 2018) were also reported to be deficient in the soils of Hawzen Woreda.

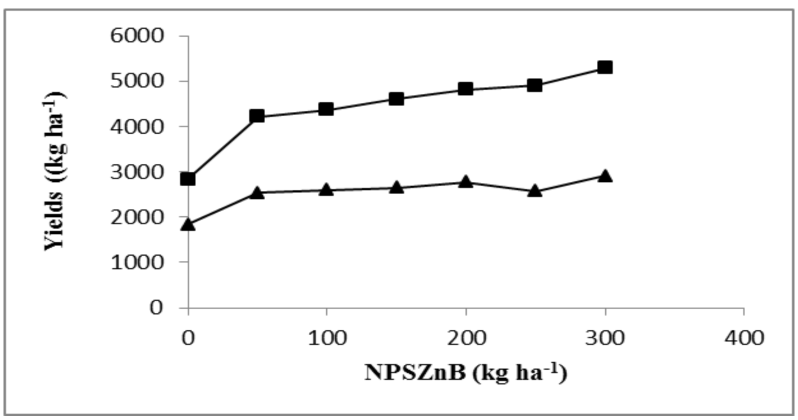

Figure2. Grain and straw yield response of NPSZnB response at adjusted N to 64 kg N ha^{-1}Hawzen Woreda, Tigray. Line and triangle indicated a curve for grain yield while line and square for straw yield.

Table 2. Main effect of year, site and blend fertilizer (NPSZnB) on yield components and yields of bread wheat

	Plant height (cm)	Spike length (cm)	Biomass yield (kg ha-^{1})	Grain yield (kg ha-^{1})	Straw yield (kg ha-^{1})	Harvest index (%)
Year						
I	64.09	7.65a	7456a	2916a	4539	38.44a
II	65.35	6.81b	6549b	2200b	4349	33.78b
P	Ns	0.004	<0.001	<0.001	ns	<0.001
LSD	Ns	0.556	383	163	ns	1.12
Site						
Site1	64.72b	6.96	8919a	3512a	5407a	38.96a
Site2	64.72b	7.49	5085d	1604d	3481c	33.26b
Site3	61.50c	7.00	7342b	2940b	4402b	39.77a
Site4	67.94a	7.45	6662c	2176c	4486b	32.45b
P	<0.001	ns	<0.001	<0.001	<0.001	<0.001
LSD	1.89	ns	542	230	363	1.59
Treatments (NPSZnB, kg ha-^{1})						
0	56.92c	6.46	4667d	1836c	2830e	38.96a
50	64.41b	7.72	6743c	2532b	4211d	36.94ab
100	64.02b	7.19	6954bc	2592ab	4362cd	36.51b
150	66.12ab	6.96	7243bc	2645ab	4598bcd	35.92bc
200	67.42a	8.47	7579ab	2768ab	4811abc	36.01bc
250	64.45b	7.13	7476abc	2574b	4902ab	33.98c
300	68.08a	7.40	8200a	2911a	5289a	34.82bc
Recommended N and P (64 N and 46 P_2O_5)	66.35ab	7.07	7154bc	2607ab	4547bcd	35.82bc
P	<0.001	0.052	<0.001	<0.001	<0.001	0.003
LSD	2.67	ns	766	326	514	2.246
P Year*Treatment	0.083	0.55	0.979	0.95	0.72	0.067
P Site*Treatment	0.99	0.90	0.984	0.89	0.97	0.26
CV (%)	5.1	18.8	13.4	15.6	14.1	7.6

Note: The100 kg NPSZnB blend fertilizer contained17.7 kg N, 34.5 kg P_2O_5, 6.5 kg S, 2.5 kg Zn and 0.5 kg B. The nitrogen content in the blend fertilizer treatments were adjusted to 64 N ha^{-1}byurea top dress application.

Partial budget analysis

Highest grain and straw yields were recorded at the highest blend fertilizer rate under adjusted N to 64 kg N ha^{-1}.Though, the recorded increases at this rate were statistically at par with NPSZnB fertilizer rate of 100 kg ha^{-1} for grain and 200kg ha^{-1} for straw. Considering only the advantage of grain yield improvement,100 kg ha^{-1} NPSZnB fertilizer with 46.3 kg N in the form of urea by top dressing would be recommended and was also statistically similar with the traditionally recommended N and P fertilizer rates. However, from biomass or grain and straw yields perspective, 200 kg ha^{-1} NPSZnB blended fertilizer with 28.6 kg N by top dressing was found to be economical to improve productivity of bread wheat under the soils similar to the experimental area in Hawzen (Table 3).

Table 3. Partial budget analysis

Treatments (NPSZnB, kg ha-[1])	Fertilizers cost (Birr)	Fertilizer transport and application cost (Birr)	Total variable cost (birr)	Total revenue (birr)	Net revenue (birr)	Marginal rate of return (ratio)	Marginal rate of return (ratio)
0	0	0	0	28205	28205		
50	2317	255	2572	41752	39180	4.27	426.76
100	2792	301	3093	42889	39796	1.18	118.25
150	3266	347	3614	44189	40575	1.50	149.52
Recmmended NP	3695	359	4054	43597	39543	D	D
200	3741	393	4134	46241	42107	2.94	294.03
250	4216	439	4655	44234	39578	D	D
300	4691	486	5176	49291	44115	1.93	192.73

Note: Farm get price for the fertilizers (Urea, blend NPSZnB and TSP) and average prices at Hawzen of wheat grain birr 13 birr kg^{-1}grain and wheat straw birr 3.2 birr kg^{-1} straw were considered to calculate the total fertilizers cost and total revenue, respectively.

Conclusion and Recommendation

The study revealed that blend NPSZnB fertilizer with adjusted N fertilizer improved grain and straw yields of bread wheat. The 200 kg ha^{-1} NPSZnB blended fertilizer adjusted with 28.6 kg N in the form of urea by top dressing was also found to be economical both from biomass or grain and straw yields improvement perspective. Improvement in grain and straw yields are equally important to farmers. From grain productivity improvement perspective, 100 kg ha^{-1} NPSZnB blended fertilizer with 46.3 kg N in the form of urea by top dressing had similar grain yield effect with previously recommended N and P rates. This indicated that the combined contribution of S, Zn and B or either of the nutrients in the blend fertilizer had also improved productivity of bread wheat. Hence, further research should be conducted to evaluate the interaction effect of N and P with the other nutrients in the blend (S, Zn and B) to find optimum interaction levels.

Reference

Anonymous (2000): Agro Ecological Zonation of Ethiopia. Ministry of Agriculture, Addis Ababa, Ethiopia. http://www.fao.org/ag/AGP/AGPC/doc/counprof/ethiopia/ ethiopia.htm).

Bereket Haileselassie (2018): Assessment of zinc and iron, zinc adsorption, and effects of zinc and iron on yields and grain nutrient concentration of tef and bread wheat in some soils of Tigray, Northern Ethiopia.PhD dissertation, Haramaya University, Haramaya, Ethiopia.

Bereket Haileselassie, Bobe Bedadi, Selamyihun Kidanu and Tekalign Mamo (2018): Effects of zinc containing fertilizers on yields and grain quality of tef [(*Eragrostis tef* (Zucc.) Trotter] in some soils of Tigray Region, Northern Ethiopia. *Ethiopian Journal of Agricultural Sciences* 28(2):23-35.

Bereket Haileselassie, Dawit Habte, Mehretab Haileselassie and Gebremedhin Gebremeskel (2014): Effects of Mineral Nitrogen and Phosphorus Fertilizers on Yield and Nutrient Utilization of Bread Wheat (*Tritcum aestivum*) on the Sandy Soils of Hawzen Woreda, Northern Ethiopia. *Agriculture, Forestry and Fisheries.* 3(3): 189-198.

Bremner JM and Mulvaney CS (1982): Total nitrogen. *In:* Page AL Miller RH and Keeney DR (eds.) In Methods of Soil Analysis, Part 2, Agronomy Society of America and Soil Science Society of America, Madison, WI, USA

Chapman HD (1965): Cation Exchange Capacity. In Black CA (eds.) In Methods of Soil Analysis, Part II, p 891-901, American Society of Agronomy, Madison, WI, USA.

Day PR (1965): Particle fractionation and particle-size analysis. In Black CA (eds.) In Method of Soil Analysis Part I, 545-567. American Society of Agronomy, Madison, WI, USA

Demeke M and Di Marcantonio F (2013): Analysis of incentives and disincentives for wheat in Ethiopia. Technical notes series, MAFAP, FAO, Rome.

FAO (2002): Web LocClim, Local Climate Monthly Estimator. http://www.fao.org/sd/ locclim/srv/locclim.home.

Hailu Beyene Franzel S and Mwangi W (1990): Constraints to increasing wheat production in Ethiopia's small-holder sector. *In:* Tanner, D.G. van Ginkel, M. and Mwangi, M. (eds), Sixth Regional Wheat Workshop for Eastern, Central and Southern Africa, D.F. CIMMITY, Mexico.

Jackson ML (1967): Soil Chemical Analysis. New Delhi: Prentice Hall of India.

Mathewos Ashamo, Tewodros Mulualem and Yasin Goa (2012) Participatory On-Farm Evaluation of Improved Bread WheatTechnologies in Some WoredaWoredas of Southern Ethiopia. *Journal of Biology, Agriculture and Health care* 2 (4), 85-88.

Ministry of Agriculture and Agricultural Transformation Agency (MoA and ATA) (2014): Soil fertility status and fertilizer recommendation Atlas for Tigray Regional State, Ethiopia. Ministry of Agriculture (MoA) and Agricultural Transformation Agency (ATA), Addis Ababa, Ethiopia.

Olsen SR Cole CV Watanabe FS and Deal LA (1954): Estimation of Available Phosphorus in Soil by Extraction with Sodium Bicarbonate. Government Printing Office, USDA Circular 939. Washington, DC, USA.

Seyoum Bediye and Sinash Sileshi (1989): The compostion of Ethiopian feeds. IAR Research Report 6. Institute of Agricultural Research, Addis Ababa, Ethiopia.

Shapiro Y (2009): Monsanto's plan and prospects for wheat improvement through breeding and biotechnology. *In:*Reynolds, M. and Eaton D. (eds). Book of Abstract. Complementary strategies to raise wheat yield potential.Workshop held at CIMMYT, D.F. CIMMYT, E. Baton, Mexico.

Tekalign Tadese (1991): Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa, Ethiopia.

VSN (2011): GenStat Fourteen (14th) Edition. VSN International Ltd, UK. www.vsni.co.uk

Evaluation of NPSZn Blended Fertilizer on Yield and Yield Traits of Bread Wheat (*Tritcum aestivum* L.) on Cambisols and Vertisols in Southern Tigray, Ethiopia

Sofonyas Dargie*, Fisseha Hadgu, Hagos Birhane, Tsigabu Mehari, Molla Hadis, Girmay Hailu and Daniel Berhe

Tigray Agricultural Research Institute, Mekelle Soil Research Center, P. O. Box 1070, Mekelle, Ethiopia

*Correspondence: sofifidel97@gmail.com

Abstract

Based on Ethiopian Agricultural Transformation Agency (ATA) and Ministry of Agriculture (MOA) soil fertility status and fertilizer recommendation atlas, one of a new blended fertilizer NPSZn containing 17.7% nitrogen (N) (17.7% N), phosphorous (P) (35.3% P_2O_5), 6% sulfur (S) and 2.5% Zinc (Zn) is recently introduced aiming at substituting di ammonium phosphate (DAP) (18% N and 46% P_2O_5) for crop production. There is a need to optimize blended fertilizer for wheat production under farmers' conditions. This study was carried out to investigate the optimum level of NPSZn blended fertilizer with adjusted N for bread wheat production. A field experiment was carried out for 2017 and 2018 main cropping seasons at Ofla and at Emba Alaje Woredas in Tigray Regional State, Ethiopia. The experiment was arranged in a randomized complete block design (RCBD) with three replications on two farmers' fields per cropping season. The treatments were seven levels of NPSZn (0, 50, 100, 150, 200, 250, 300, kg ha^{-1}) adjusted with N to the recommended level. Recommended N and P fertilizers (64 kg N ha^{-1}, 46 kg P_2O_5 ha^{-1}) were also included as a positive control. Soil samples were collected before planting and analyzed for selected physicochemical properties. Application of different rates of NPSZn blended fertilizer significantly influenced yield and yield components of wheat at both sites. The response curve revealed that grain and straw yield increased with rate at both sites. At Ofla, the highest grain and straw yields were obtained from plots that received 200 kg NPSZn ha^{-1} . At Emba Alaje, the highest grain and straw yields were harvested from the application of 200 kg NPSZn ha^{-1} and 100 kg NPSZn ha^{-1}, respectively. Partial budget analysis revealed that the optimum marginal rate of return was 22.25ETB and 16.06ETB at Emba Alaje and Ofla, respectively. Both biological and economic analysis showed that applications of 200kg NPSZn with 28.6 kg N at Ofla and 100 kg NPSZn with 46 kg N at Emba Alaje were optimum for wheat production and these rates could be recommended for areas where the rainfall distribution and soil type is similar with the WoredaWoredas wherein this experiment was conducted. Further study should be done on effects of NPSZn in grain quality and single nutrient based experiment should also be carried out to evaluate the blended fertilizer for crop production.

Keywords: NPSZn, Wheat, Recommended NP, Tigray

Introduction

Ethiopia's current wheat production and productivity is getting improved. Despite this, with Ethiopia's rising population and urbanization, demand for wheat surpasses the national supply which makes the current production insufficient to meet domestic needs, forcing the country to import up to 50% to fill the gap (Minot et al 2015). The low yield is mainly allied with the depletion of soil organic matter, continuous nutrient uptake of crops, mono cropping in the major wheat growing areas of the country, improper use of fertilizer and low fertilizer recovery, occurrence of disease and pest. To meet the growing demand without importing wheat, either the area under wheat production and/or productivity per unit area should be increased (Kamruzzaman and Mohammad 2008). Varietal development and adoption of improved agricultural technology including soil fertility and fertilizer management are among the essential tools to improve productivity of wheat per unit area.

The use of different blended fertilizers for crop production in Ethiopia is a recent history. For the past 5 decades fertilizer recommendation in Ethiopia was based on very general crop specific guidelines or more often, a single recommendation for all crops (100 kg DAP (18-46-0) and 100 kg Urea (46-0-0). This blanket recommendation often fails to take into consideration differences in resource endowment (soil type, labor capacity, climate risk) or make allowances for dramatic changes in input/output price ratio, thereby discouraging farmers from fertilizer application. Moreover, the nutrients in the blanket recommendation were not well balanced agronomically and its continued use will gradually exhaust soil nutrient reserves. Therefore, neither yields nor profits can be sustained using imbalanced application of fertilizers, as the practice results in accelerating deficiencies of other soil nutrients. Since absence of one or more nutrients besides N and P can depress yield significantly. This could explain, in part, the modest crop yield improvements observed over the last few decades in contrast to significant increases in fertilizer use and investment made in the country. NPSZn blended fertilizer is one of the newly introduced fertilizers to improve crop production based on the ATA soil atlas map in our country (ATA 2014). A different level of NPSZn with adjusted N for wheat production was not yet investigated in our country. Hence, the experiment was initiated to evaluate different rates of blended fertilizer on yield and yield components of wheat.

Materials and Methods

Description of the study area

The experiment was carried out for the two consecutive raifed cropping seasons (2017 and 2018) in Ofla at two farmers' field and in 2018 in Emba Alaje at two farmers' fields (Figure 1).

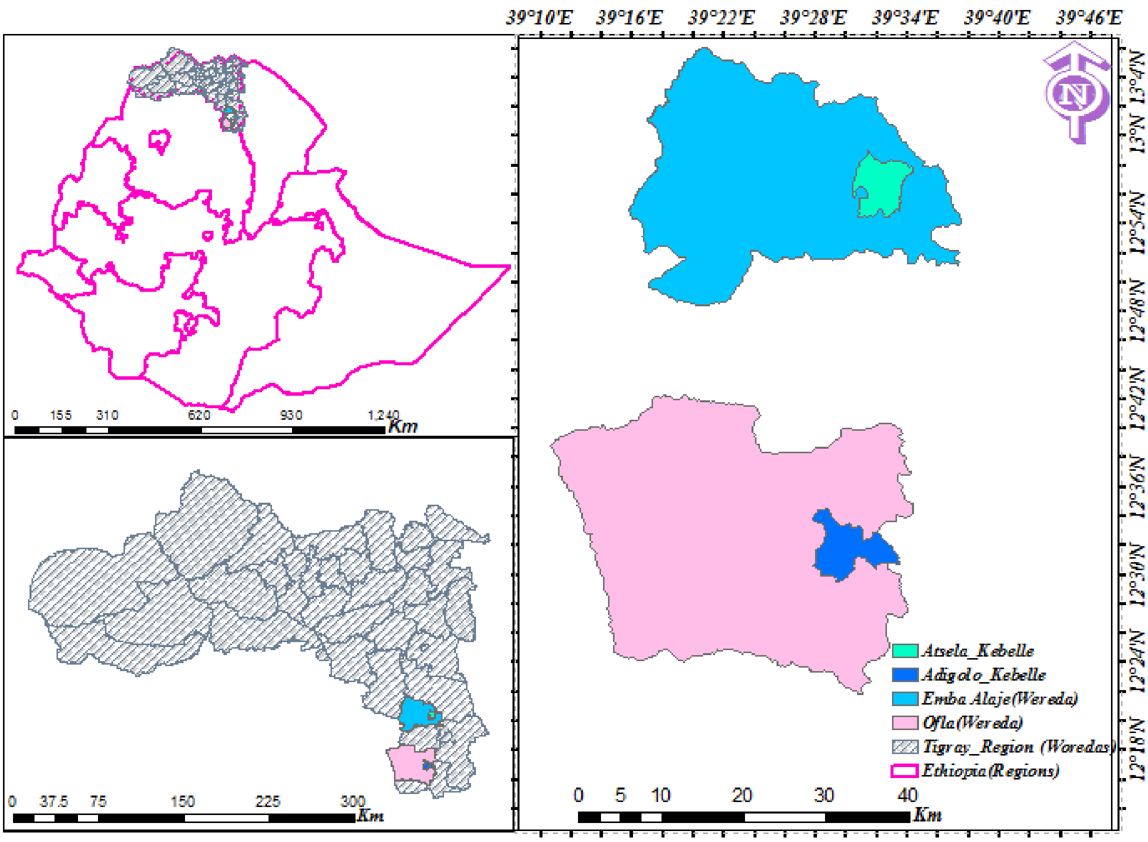

Figure 1. Location map of Emba Alaje and Ofla Woreda, Tigray, Ethiopia

The trial was laid out in RCBD with three replications. The treatments were seven levels of NPSZn (0, 50, 100, 150, 200, 250, 300, kg ha^{-1}) adjusted with N to the recommended level. Recommended N and P fertilizers (64 kg N ha^{-1}, 46 kg P_2O_5 ha^{-1}) were also included as a positive control.

Table1. Treatments with respective nutrient composition

Treatments (kg ha^{-1})	N	P_2O_5	S	Zn	Adjusted N	Total N applied
0	-	-	-	-	-	-
50 NPSZn	8.85	17.65	3	1.25	55.15	64
100 NPSZn	17.7	35.3	6	2.5	46.3	64
150 NPSZn	26.55	52.95	9	3.75	37.45	64
200 NPSZn	35.4	70.6	12	5	28.6	64
250 NPSZn	44.25	88.25	15	6.25	19.75	64
300 NPSZn	53.1	105.9	18	7.5	10.9	64
64 N and 46 P2O5	64	46	-	-	-	64

Soil Sampling and Analysis

Representative composite soil samples from each field were taken before planting following the standard soil sampling procedure. Each composite soil sample was used for selected physico-chemical analysis [particle size analysis, soil reaction (pH), electrical conductivity (EC) , organic carbon (OC), cation exchange capacity (CEC), total N, and available P]. Particle size distribution was determined using the Bouyoucos hydrometer method (Bouyoucos, 1962). The pH of the soil was measured in the supernatant suspension of a 1: 2.5 soil to water ratio using a pH meter

(Rhoades, 1982). Walkely and Black (1934) used for determination of organic carbon. Total N was determined using the Kjeldahl method as described by (Bremner and Mulvaney 1982). Available P was determined following the Olsen method (Olsen et al 1954) using ascorbic acid as reducing agent. Cation exchange capacity was determined by ammonium acetate method.

Data collection

Plant height (PH) was measured from ground surface to the tip of the panicle at maturity from 5 randomly sampled plants using tape meter (cm). Spike length (SL) was measured from the bottom of the spike to the tip of the spike excluding the awns from five randomly tagged spikes from the net plot. Grain yield was harvested from the five middle rows of each plot, sun dried and manually threshed separately then grain was weighed by using sensitive electronic balance. The weight of above ground crop biomass in middle five rows in each plot was recorded after sun drying. Harvest index was calculated from the ratio of grain yield to biological yield.

Data analysis

Collected data were subjected to analysis of variance (ANOVA) using General Linear Model (GLM) procedures of SAS 9.1.3 (SAS, 2002). Mean separation was carried out following Gomez (1884) and economic feasibility following International Maize and Wheat Improvement Center (CIMMYT) manual (CIMMYT, 1988).

Results and Discussion

Before planting soil properties

The physicochemical properties of the soils of the experimental sites are indicated in Table 2. Textural class at both sites was clay loam. According to Tekalign (1991) rating of soil pH, the pH of Cambisols of Ofla was slightly acidic at both sites. The OC contents of soils of the experimental sites were low (Tekalign, 1991). According to Birhanu (1980), total N content at both sites were low. Available P was medium (Olsen, 1954) and CEC was medium at both sites (Landon, 1991).

Table 2. Pre-planting soil physico-chemical properties in Ofla and Emba Alaje Woredas

Parameters	Emba Alaje Woreda		Ofla Woreda			
	2018		2017		2018	
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
pHwater (1:2.5)	6.97	6.83	5.86	6.96	6.46	6.69
ECwater (1:2.5), dS m-1	0.115	0.138	0.09	0.66	0.132	0.075
Organic carbon (%)	1.609	2.116	1.14	0.87	0.935	1.566
Total N (%)	0.102	0.113	0.078	0.144	0.08	0.12
P-Olsen (mg kg-1)	11.2	14.8	13.48	20.28	17.342	18.54
CEC (meq/100 gm soil)	33.36	35.97	25.9	19.7	39.7	43.79
Clay (%)	36	22	22	66	56	58
Silt (%)	38	52	36	14	26	24
Sand (%)	26	26	42	20	18	18
Texture class	Clay loam	Silt loam	Loam	Clay	Clay	Clay

Yield and yield components

Results showed that application of different rates of NPSZn blended fertilizer had a significant ($P<0.001$) effect on plant height and spike length in Ofla and Emba Alaje Woredas (Tables 4 and 5. Even though there was some inconsistency, plant height increased with rate at both sites. The highest plant height was recorded from the application of 300 kg of NPSZn ha^{-1} at both sites. Blended rates ranging from 100 to 300 kg ha^{-1} NPSZn rates were statistically ($P<0.001$) higher in plant height than the recommended NP. Grain and straw yields increased consistently up to 200 kg NPSZn ha^{-1} at both Woreda, and started to decrease with rates. In Emba Alaje the highest grain and starw yields were obtained from the application of 200 kg NPSZn ha^{-1} and 100 kg NPSZn ha^{-1}, respectively, whereas in Ofla Woreda the highest grain and starw yields were recorded on plots treated with 200kg NPSZn/ha and 300 kg NPSZn/ha, respectively.

Table 3. Effect of NPSZn on yield and yield components of wheat in Ofla

Treatments	Ofla				
	Two Year Combined analysis				
	Plant H (cm)	Spike L (cm)	Grain Yield kg ha^{-1}	Straw Yield kg ha^{-1}	Harvest Index (%)
0 NPSZn	65.25e	5.175d	1697.6c	2722.3d	0.38c
50 NPSZn	73.3d	5.9917c	2979.9b	3879.8c	0.42ab
100 NPSZn	75.65cd	6.525b	2997.6b	3933.4c	0.43a
150 NPSZn	77.533bc	6.6917ab	3037.4b	4074.7c	0.43a
200 NPSZn	80.16a	6.658b	3580.2a	4956.8a	0.42ab
250 NPSZn	79.5ab	6.66ab	3168.0ab	4555.6ab	0.41ab
300 NPSZn	80.967a	7.0a	3388.4ab	4972.7a	0.4b
Rec.NP(64N,46 P_2O_5)	77.083bc	6.74ab	3035.2b	4174.6bc	0.41ab
LSD (0.05)	2.42	0.3417	423.7	439.5	0.022
CV (%)	3.9	6.51	17.39	12.95	6.59
P Value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Year	NS	<0.0001	<0.0001	<0.0001	<0.0001
Site	<0.0001	NS	<0.0001	<0.0001	<0.0001
Trt*Year	NS	NS	NS	NS	NS
Trt*Site	0.0017	NS	NS	NS	0.0194
Trt*Year*Site	0.0408	<0.0001	NS	0.0019	NS

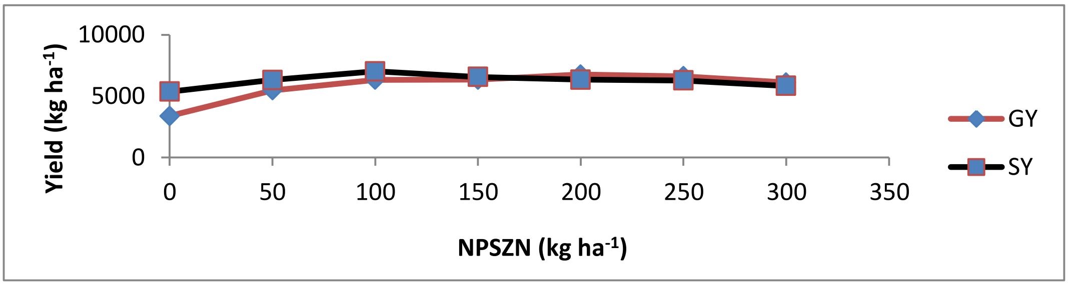

Figure 2. Wheat reponse curve to NPSZn rates at Emba Alaje

Table 4. Effect of NPSZn on yield and yield components of wheat in Emba Alaje

Treatments	Emba Alaje				
	Two Site Combined analysis				
	Plant H (cm)	Spike L (cm)	Grain Yield kg ha^{-1}	Straw Yield kg ha $^{-1}$	Harvest Index (%)
0 NPSZn	85.8b	8.26	3380.2c	5364.3b	0.40b
50 NPSZn	88.0ab	8.6	5463.9b	6313.9ab	0.46ab
100 NPSZn	88.4ab	8.18	6327.8ab	7011.1a	0.47ab
150 NPSZn	88.6ab	8.4	6344.4ab	6555.6ab	0.49a
200 NPSZn	87.4ab	8.28	6755.6a	6344.4ab	0.52a
250 NPSZn	88.4ab	8.38	6619.4a	6269.4ab	0.51a
300 NPSZn	90.5a	9.1	6108.3ab	5830.6ab	0.50a
Rec.NP(64N,46 P_2O_5)	87.5ab	8.8	6682.2a	6095.6ab	0.53a
LSD (0.05)	3.83	NS	927.7	1413.9	0.0735
CV (%)	3.71	10.39	13.3	19.42	12.83
P Value	0.0271	0.103	<0.0001	0.0022	0.0251

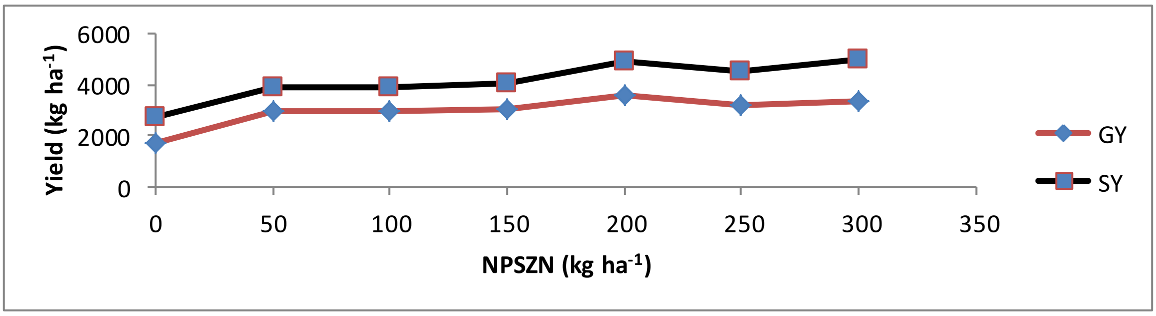

Figure 3. Wheat response curve to NPSZn rates at Ofla

Table 5. Partial budget analysis in Emba Alaje

Treatments	Adjusted grain yield (kg ha^{-1})	Adjusted straw yield (kg ha^{-1})	Total variable cost (TVC)	Grain revenue*13	Straw revenue*3.2	Total revenue	Net revenue [TR-TVC]	MRR (ratio)	MRR (%)
0	3042.2	4827.9	0.0	39548.3	15449.2	54997.5	54997.5		
50	4917.5	5682.5	2571.7	63927.6	18184.0	82111.7	79540.0	9.5	954.3
100	5695.0	6310.0	3092.6	74035.3	20192.0	94227.2	91134.6	22.3	2225.8
150	5710.0	5900.0	3613.5	74229.5	18880.1	93109.6	89496.1	D	D
Rec NP	6014.0	5486.0	4053.8	78181.7	17555.3	95737.1	91683.3	D	D
200	6080.0	5710.0	4134.4	79040.5	18271.9	97312.4	93178.0	18.5	1853.0
250	5957.5	5642.5	4655.4	77447.0	18055.9	95502.9	90847.5	D	D
300	5497.5	5247.5	5176.3	71467.1	16792.1	88259.2	83083.0	D	D

Table 6. Partial budget analysis in Ofla

Treatments	Adjusted grain yield (kg ha^{-1})	Adjusted straw yield (kg ha^{-1})	Total variable cost (TVC)	Grain revenue*13	Straw revenue*3.2	Total revenue	Net revenue [TR-TVC]	MRR (ratio)	MRR (%)
0	1527.8	2450.1	0.0	19861.9	7840.2	27702.1	27702.1		
50 NPSZn	2681.9	3491.8	2571.7	34864.8	11173.8	46038.7	43467.0	6.1	613
100 NPSZn	2697.8	3540.1	3092.6	35071.9	11328.2	46400.1	43307.5	D	D
150 NPSZn	2733.7	3667.2	3613.5	35537.6	11735.1	47272.7	43659.2	D	D
Recommended NP	2731.7	3757.1	4053.8	35511.8	12022.9	47534.7	43480.9	D	D
200 NPSZn	3222.2	4461.1	4134.4	41888.3	14275.6	56163.9	52029.5	16.1	1606
250 NPSZn	2851.2	4100.0	4655.4	37065.6	13120.1	50185.7	45530.4	D	D
300 NPSZn	3049.6	4475.4	5176.3	39644.3	14321.4	53965.7	48789.4	D	D

Partial budget analysis of NPSZn rates

Partial budget results showed that highest marginal rate of return was obtained from the application of 200 kg NPSZn with 28.6 kg N ha^{-1} at Ofla and 100 kg NPSZn with 46 kg N ha^{-1} at Emba Alaje (Table 5 and 6). According to the manual for economic analysis of CIMMYT (1988), the recommendation is not necessarily based on the treatment with the highest marginal rate of return compared to that of neither next lowest cost, the treatment with the highest net benefit, and nor the treatment with the highest yield.The identification of a recommendation is based on a change from one treatment to another if the marginal rate of return of the change is greater than the minimum rate of return (100%). The marginal rate of return revealed that recommended NP had negative rate or return in Ofla. The marginal rate of return ratio was 22.25 and 16.06 at Emba Alaje and Ofla, respectively.

Conclusion and Recommendation

Application of different rates of NPSZn blended fertilizer significantly influenced yield and yield components of wheat at Emba Alaje and Ofla WoredaWoredas. The response curve revealed that grain and straw yields increased with rate at both sites. In Ofla the highest grain and straw yields were obtained from plots that received 200 kg NPSZn ha^{-1} . At Emba Alaje, the highest grain and straw yields were harvested from the applications of 200 kg NPSZn ha^{-1} and 100 kg NPSZn ha^{-1} , respectively. Both biological and economic analysis showed that application of 200kg NPSZn with 28.6 kg ha^{-1} N. In Ofla and 100 kg ha^{-1} NPSZn with 46 kg ha^{-1} N at Emba Alaje was is optimum for wheat production and in areas where the rainfall distribution and soil type is similar with the Woredas where this experiment was conducted. Further study should be done on effects of NPSZn in grain quality and single nutrient based experiment should also be carried out to evaluate each nutrient contribution for wheat production.

Acknowledgements

The authors are grateful to AGP II (Agricultural Growth Program II Research Component) for their financial support.

Reference

Walkley A and Black I A (1934): An examination of the Degtjareff method for determining soil organic matter and proposed chromic acid titration method. Soil Science, 37: 29-38.

Olsen R, Cole S, Watanabe F and Dean L (1954): Estimation of available phosphorus in soils by extraction with sodium bicarbonate. United States Department of Agriculture Circ. 939.

Bremner J M and Mulvaney C S (1982): Nitrogen - Total, Methods of soil analysis. Part 2- Chemical and microbiological properties. Agronomy, 9 (2):595-624. American Society of Agronomy Madison, Wis.

Black C A, Evans D D, White J L, Ensminger LE, and Clark F E (1965): Method of Soil Analysis, Part 2. ASA, Inc. Madison, Wis, USA.

FAO (Food and Agricultural Organization) (2008): Guide to laboratory establishment for plant nutrient analysis, fertilizer and plant nutrition bulletin 19 Rome.
EthioSIS (Ethiopian Soil Information System) (2014): Atlas for Tigray regional state. Soil fertility status and fertilizer recommendation, EthioSIS, report.
Bouyoucos J (1962): Hydrometer method improved for making particle size analysis of soil. Agronomy Journal, 54:464-465.
Blake C A (1965): Methods of soil analysis. Part I, American Society of Agronomy. Madison, Wisconsin, USA.
USDA (United States Department of Agricultural) (2008): Soil Quality indicators, Nyle C. Brady, Macmiillan Publishing Company.
Rhoades J and Corwin D (1990): Soil electrical conductivity: effects of soil properties and application to soil salinity appraisal. Communication in Soil Science and Plant Analyses, 21(9): 836-860.
Hazelton P and Murphy B (2007): Interpreting soil test results: What do all the numbers mean? 2nd ed. CSIRO Publishing.
SAS (2002): SAS/STAT User's Guide, Version 9.1.3. SAS institute Inc., Cary, NC.
Gomez and H Gomez (1984): Statistical analysis for agricultural research.John Willy and Sons Inc. pp.120-155.
Landon J R (1991): Booker Tropical Soil Manual: A hand book for soil survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical, Essex, New York. 474p. OR John Wiley & Sons Inc., New York.
International Maize and Wheat Improvement Center (CIMMYT) (1988): From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico.
Tekalign Tadese (1991): Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa.
Minot N, Warner J, Lemma S, Kassa L, Gashaw A, and Rashid S (2015): The wheat supply chain in Ethiopia: Patterns, Trends, and Policy options. International Food Policy Research Institute (IFPRI) Washington, DC.

Optimizing the Rate of NPS and Urea Fertilizers on Yield of Wheat in Enderta Woreda, under Rain-fed Condition on Cambisols and Vertisols of Tigray

Fisseha Hadgu*, Sofonyas Dargie, Hagos Brhane, Mehretab Haileselassie, Gebremedhin Berhe, Mola Haddis and Gebrejewergis Aredahay

Tigray Agricultural Research Institute, Mekelle Soil Research Center, P. O. Box 1070, Mekelle, Ethiopia
*Correspondence: habenfhb@gmail.com

Abstract

Two factorial field experiments were carried out with the objective of evaluating the effects of NPS and urea fertilizer rates on yield and yield component of bread wheat (Kakaba variety) on Vertisols and Cambisols at Shibta in Enderta Woreda of Tigray during the main rainy season of 2017. The experiments were carried out at farmers' fields with three replications using randomized complete block design (RCBD), comprised of 16 treatments which were combinations of four NPS levels 0, 100, 150 and 200, kg/ha NPS and four levels of urea (0,50,100 and 150 kg/ha). Composite soil samples were also initially collected from 0-20 cm of the fields and analyzed to determine major soil characteristics. The NPS fertilizer rates were applied at the time of sowing while nitrogen (N) was applied in the form of urea splitted into two applications. Spike length, plant height, effective tillering (ET), straw and grain yield data were collected. Crop data were analyzed using Statistical Analysis System (SAS) program. Textural classes of the experimental sites were clay and loam, mildly alkaline to neutral soil reaction (pH), non saline Electrical Conductivity (EC), low organic carbon (OC),Very low to low total N, moderate and high Olsen phosphorus (P) and low available potassium (K). Interaction effects of NPS and urea for the season were not significantly different for all crop parameters tested. Significant differences ($P \leq 0.001$) were observed due to main effect of NPS on plant height, spike length, effective tillering, straw yield and grain yield. However, the main effects of urea showed significant differences ($P \leq 0.05$) on plant height, spike length and effective tillering except on grain and straw yield which were not significant.The main effects of NPS showed significantly different ($P = 0.001$) highest agronomical results at the rates of 200 kg NPS/ha (2856.3 kg/ha) on Vertisols but the main effect of urea was not significant with higher yield (2464.6 kg/ha) at 50 kg urea/ha on this soil.The main effects of NPS showed significantly different ($P = 0.001$) highest agronomical results at the rates of 150 kg NPS/ha (3602.1kg/ha) on Cambisols but the main effect of urea was not significant with higher yield (3160.kg/ha) at 150 kg urea/ha on this soil. Partial budget analysis showed highest and profitable yield at 150 kg NPS/ha with 50 kg/ha urea for Cambisols at Shibta in Enderta for wheat. The analysis indicated profitable grain yield at 100kg NPS/ha for Vertisols in the area. These profitable rates could be recommended for the respective soil types of the experimental areas and other areas with same soil type and agro-ecology in Tigray.

Keywords: Cambisols, Vertisols, NPS, urea, wheat, soil characteristics

Introduction

Balanced fertilizers containing N, P, K, sulfur (S), boron (B) and zinc (Zn) in blend form have been recommended to ameliorate site specific nutrient deficiencies and thereby to increase land, water and labour productivity. The need for site-specific fertilizer prescriptions are increasingly apparent, however, fertilizer trials involving multi-nutrient blends that include micronutrients are rare in the Ethiopian context. Although there is a general perception that the new fertilizer blends are better than the traditional fertilizer recommendation [urea and di ammonium phosphate (DAP)], their comparative advantages is not explicitly examined and understood under various production environment.

Based on soil fertility map of 150 Woredas, seven fertilizer blend formulas have been developed to ameliorate site specific nutrient deficiencies (N, P, K, S, Zn and B) and thereby increase land, water and labor productivity. The need for site-specific fertilizer prescriptions is increasingly apparent, however, fertilizer trials involving multi-nutrient blends that include micronutrients are rare. Furthermore, evaluation of yield response to multi-nutrient fertilization have not been undertaken. Validation of fertilizer blend formula prescribed based on soil fertility maps and provisional area specific fertilizer recommendations were undertaken. Therefore, this study was aimed to determine the optimum level of NPS and urea fertilizers

Materials and Methods

Description of the study area

The mean annual rainfall of Shibta calculated from meteorological data taken from Alula Aba Nega Airport for the period 2008 to 2017 was 335.2 mm. The annual rainfall of Shibta in 2017 was 440.5mm of which 359.5 mm was calculated for the period of June to September.

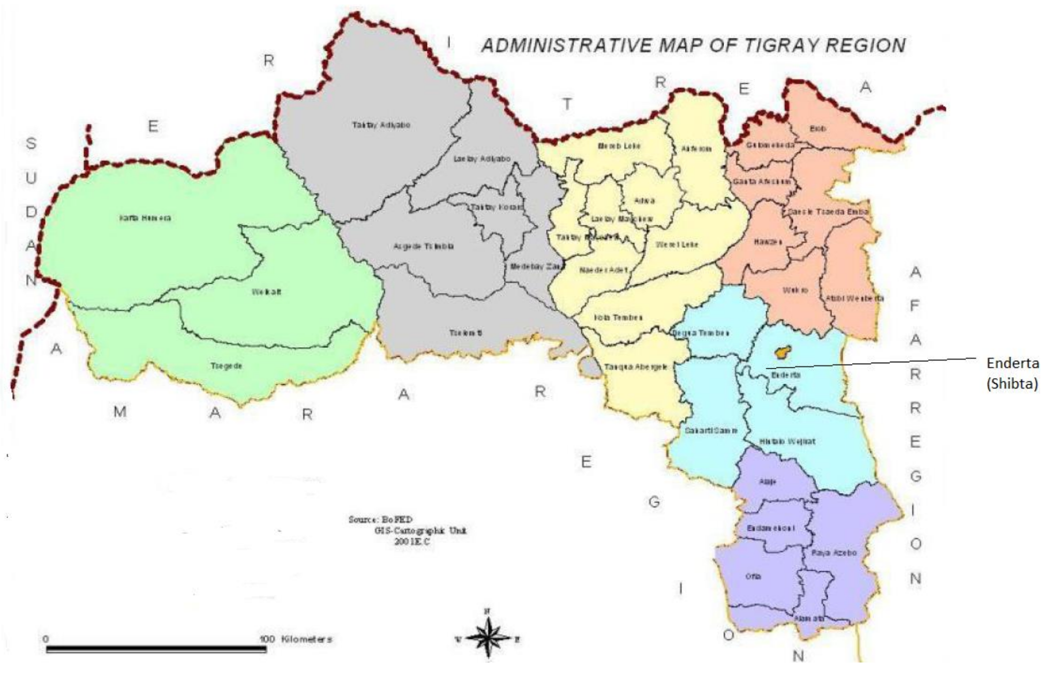

Figure 1. Location map of Enderta, Woreda, Tigray, Ethiopia

Field experimental design and layout

Two experiments were laid down in RCBD in three replications, at farmers' fields during the 2017 rainy season, having 16 treatments (NPS= 0, 100, 150, 200 kg/ha and urea= 0, 23, 46 and 69 kg/ha in factorial combination) at Shibta in Enderta Woreda on wheat. Kakaba wheat variety was sown at a seed rate of 150 Kg ha^{-1} in an experimental plot area of 3m by 3m. Nitrogen treatments applied in the form of urea were splitted into two applications (one at planting and the second after 45 day while NPS was applied at planting time).

Soil Sampling and Analysis

Soil samples from the farmers' experimental fields were collected before planting at the depths of 0-20 cm for determination of soil characteristics. The composite soil samples were air dried, crushed using pestle and mortar and passed through a 2 mm diameter sieve. Particle size distribution, pH, EC, available P, available K and cation exchange capacity (CEC) were then analysed in Mekelle Soil Research Center soil laboratory. Portions of the soil samples were taken and sieved using 0.5 mm diameter for the determinations of OC and total N (TN).

Soil texture was determined by the hydrometer method (Bouyoucos, 1962). Once the sand, silt, and clay separates were calculated in percent, the soil was assigned to a textural class based on the soil textural triangle using International Soil Science Society (ISSS) system (Rowell, 1994) , soil pH was determined using a pH meter using a soil: water ratio of 1:2.5 as described in Rhoades (Rhoades, 1982).The EC of the soil was measured according to the method described by Peech (1965). The CEC was determined using the method described by Chapman (1965), OC was determined by oxidizing the soil with potassium dichromate and concentrated sulfuric acid and the remaining concentration of dichromate and ferrous ions determined by titration (Walkley and Black, 1934).The total N content in soils was determined using the Kjeldahl procedure by oxidizing the organic matter with sulfuric acid and converting the N into ammonium ion (NH_4^+) as ammonium sulfate (Sahlemedhin and Taye, 2000). Available P was extracted through the Olsen method, using 0.5 M NaHCO3 at pH 8.5 (Olsen 123 et al 1954). Available K was determined using flame photometer.

Data analysis

The effects of treatments on biomass and grain yields, plant height, spike length, harvest index, number of tillers per plant and number of effective tillers per plant were determined using analysis of variance. Combined analyses of variance were also carried out when necessary. Analyses of variance on these variables were performed using Statistix 10 software (Analytical Software, 1985-2013). Least Significant Difference (LSD) was used to separate means for the treatment effects.

Result and Discussion

Soil properties before planting

The textural classes of the soils were clay for Vertisols and loam for Cambisols at Shibta, none saline in EC in the two sites, neutral for Cambisols and mildly alkaline for Vertisols in pH according to the ratings by Bruce and Rayment (1982), high in the CEC for both soils with reference by Landon (1991) ,low in OC for the two soil types, Very low and low in TN and very high for both soils,and moderate for Cambisols and high for Vertisols in available P as well as low in available K for the two soil types as indicated by Olsen (1954) (Table 1).

Yield and yield component

All yield and yield parameters (Straw yield, grain yield, PH, SL and No. effective tillers) responded significantly to the NPS and non significantly to N on Vertisols at shibta. Highest straw and grain yields were recorded at the application rates of 200 kg/ha NPS (Table 2).

Table 1. Initial soil characteristics of the experimental field in Enderta Woreda (Shibta)

Parameter*	Shibta (Cambisols)	Shibta (Vertisols)
pH (1:2.5)	7.12	7.46
EC	1.41	1.0
OC (%)	0.92	0.96
T.N (%)	0.029	0.06
Olsen P	10.48	21.08
Av. K (ppm)	34.2	64.3
CEC	32.34	28.61
Sand (%)	22	22
Silt (%)	42	36
Clay	20	42
Textural class	Loam	Clay

Yield and yield parameters (Straw yield, grain yield, plant height and number of effective tillers/plant) responded significantly to the effect of NPS on Cambisols at shibta (Table 3). However, spike length showed no significant difference due to application of the NPS. Higher straw yield was obtained at 200 kg/ha NPS and higher grain yields were recorded at the application rates of 150 kg/ha NPS. All yield parameters responded non significantly to N on Vertisols at shibta (Table 2).

Table 2. Effect of NPS and urea on yield and growth of wheat on Vertisols in Enderta (Shibta)

NPS (kg /ha)	PH* (cm)	SL (cm)	ET (cm)	GY (kg/ha)	SY (kg/ha)
0	50.6b	5.38b	2.21b	1418.8b	2379.2c
100	72.4a	7.4a	3.03a	2810.4a	4593.8b
150	73.0a	7.71a	2.98a	2639.6a	4847.9b
200	74.9a	7.73a	3.10a	2856.3a	5725.0a
LSD (0.05)	2.98	0.38	0.38	412.52	436.38
CV (%)	5.29	6.55	16.42	20.4	11.96
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
			Nitrogen Rate		
N (Kg/ha)	PH (cm)	SL (cm)	ET (cm)	GY (kg/ha)	SY (kg/ha)
0	66.10b	6.68b	2.85	2450.0	4283.3
50	69.85a	7.31a	2.85	2464.6	4341.7
100	67.31ab	7.11a	2.85	2445.8	4293.8
150	67.73ab	7.16a	2.78	2364.6	4627.1
LSD (%)	2.98	0.38	NS	NS	NS
CV	5.29	6.55	16.42	20.4	11.96
P value	0.0985	0.0139	0.9797	0.9597	0.3851
NPS*N rate	NS	NS	NS	NS	NS

* = PH = Plant height, SL = Spike length, ET= Effective tillering, GY = Grain yield, SY = Straw yield, LSD = List Significant Difference, CV= Coefficient of Variation and NS = None Significant.

Table 3. Effect of NPS and urea on yield and growth of wheat on Cambisols of Enderta (shibta)

NPS (kg/ha)	PH* (cm)	SL (cm)	ET (cm)	GY (kg/ha)	SY (kg/ha)
0	77.26b	7.79	2.7b	2231.3c	4614.6b
100	79.33ab	7.71	3.06ab	2816.7bc	5464.6ab
150	81.95a	8.01	2.98ab	3602.1a	6010.4a
200	81.56a	7.98	3.2a	2970.8b	6141.7a
LSD (0.05)	3.03	NS	0.38	621.96	987.08
CV (%)	4.54	7.08	15.36	25.74	21.35
P value	0.012	0.47	0.07	0.0011	0.0143
			Nitrogen Rate		
Urea (kg/ha)	PH (cm)	SL (cm)	ET (cm)	GY(kg/ha)	SY (kg/ha)
0	77.71b	7.5b	2.93	2495.8b	4862.5b
50	79.83ab	7.78ab	3.10	2839.6ab	5583.3ab
100	82.11a	8.1a	2.96	3125.0a	5493.8ab
150	80.45ab	7.9ab	2.95	3160.4a	6291.7a
LSD (%)	3.03	0.45	NS	621.	999.02
P value	0.045	0.06	0.80	0.12	0.049
NPS*N rate	NS	NS	NS	NS	NS
CV	4.54	7.08	15.36	25.74	21.35

* = PH = Plant height, SL = Spike length, ET= Effective tillering, GY = Grain yield, SY = Straw yield, LSD = List Significant Difference, CV= Coefficient of Variation and NS = None Significant.

Partial budget analysis

Partial budget analysis of the main effect of NPS on grain and straw yields showed highest marginal rate of returns at the rates of 200 for Vertisols at Shibta in Enderta (Table 4). Partial budget analysis of the main effect of NPS on grain and straw yields showed highest marginal rate of returns at the rates of 150 for Cambisols at Shibta in Enderta (Table 5). Partial budget analysis of the main effect of urea on grain and straw yields showed highest marginal rate of returns at the rates of 200 for Cambisols at Shibta in Enderta (Table 6).

Table 4. Partial budget analysis for using main effect of NPS Enderta (Shibta) Vertisols

*Trt (NPS)	Adjusted GY	Adjusted SY	TVC	Grain revenue	Straw revenue	Total revenue	Net revenue	MRR (ratio)	MRR (%)
0	1276.9	2141.3	0.0	17876.9	6852.1	24729.0	24729.0		
100	2529.4	4134.4	1659.0	35411.0	13230.1	48641.2	46982.2	13.4	1341.3
150	2375.6	4363.1	2488.5	33259.0	13962.0	47220.9	44732.4	D	
200	2570.7	5152.5	3318.0	35989.4	16488.0	52477.4	49159.4	1.3	131.2

* GY = Grain yield; SY = straw yield; TVC = Total variable cost, MRR = Marginal rate of return

Table 5. Partial budget analysis using main effect of NPS for Enderta (Shibta) Cambisols

Trt (NPS)	Adjusted GY	Adjusted SY	TVC	Grain revenue	Straw revenue	Total revenue	Net revenue	MRR (ratio)	MRR (%)
0	2008.2	3253.1	0.0	28114.4	6506.3	34620.7	34620.7		
100	2535.0	4918.1	1659.0	35490.4	9836.3	45326.7	43667.7	5.5	545.3
150	3241.9	5409.4	2488.5	45386.5	10818.7	56205.2	53716.7	12.1	1211.5
200	2673.7	5527.5	3318.0	37432.1	11055.1	48487.1	45169.1	D	

* GY = Grain yield; SY = straw yield; TVC = Total variable cost, MRR = Marginal rate of return

Table 6. Partial budget analysis using main effect of urea for Enderta (Shibta) Cambisols

Trt (urea)	Adjusted GY	Adjusted SY	TVC	Grain revenue	Straw revenue	Total revenue	Net revenue	MRR (ratio)	MRR (%)
0	2246.2	4376.3	0	31447.1	8752.5	40199.6	40199.6		
50	2555.6	5025.0	762	35779.0	10049.9	45828.9	45066.9	6.4	638.8
100	2812.5	4944.4	1524	39375.0	9888.8	49263.8	47739.8	3.5	350.8
150	2844.4	5662.5	2286	39821.0	11325.1	51146.1	48860.1	1.5	147.0

Conclusion and Recommendation

Higher agronomic grain response was observed in the rate of 200 kg NPS/ha showing no significant differences with the applications of 100 and 150 kg/ha NPS on Vertisols at Shibta (Enderta). Even though highest profitable response was obtained at 200 kg NPS/ha on the Vertisols, 100-200 kg NPS/ha could be recommended for Vertisols at Shibta. However, for Cambisols in the same location, 150 kg/ha NPS could be recommended since both the agronomic as well as economic maximum were obtained at this rate. Highest biological yield and profitable grain and straw yields were recorded at the rate of 150 kg urea/ha but 50-150 kg/ha urea could be recommended for the Cambisols at Shibta (Enderta) for the reason that no agronomic yield differences were observed among the three last urea treatments.

Acknowledgements

We would like to thank Mekelle Soil Research Center for its support in the implementation of this study by providing vehicle and for its financial sponsorship. We are also grateful to Mr. Girmay Hailu, Lijalem G/Egziabher, Hagos W/Gebriel and other laboratory staff for their contribution in soil analysis in soil laboratory of Mekelle Soil Research Center.

References

Analytical Software (2013): Statistix 10 User's Manual. Analytical Software, Tallahassee, FL.ATA (Ethiopian Agricultural Transformation Agency) and MoA (Ministry of Agriculture) (2014): Soil Fertility Status and Fertilizer Recommendation Atlas for Tigray Regional State, Ethiopia.

Bouyoucos GJ (1962): Hydrometer method improved for making particle size analyses of soil. Agron. J., 53: 464-465.

Chapman HD (1965): Cation exchange capacity. Part II. In*:* Black CA,Evans DD, Ensminger JL, Clark FE, eds. Methods of soil analysis., Madison, WI, USA : ASA, p.891-901.

Charman PE and Roper MM (2007): Soil organic matter. In: Charman P.E., Murphy B.W., eds. Soils-their properties and management, 3rd edition. Melbourne, Australia: Oxford University Press, pp. 276-285.

CIMMYT (International Maize and Wheat Improvement Center) (1988): From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico.

Cottenie A (1980): Soil and plant testing as a basis of fertilizer recommendations.FAO soil bulletin 38/2. Food and Agriculture Organization of the United Nations,Rome.

CSA(Central Statistical Agency) (2007): Ethiopianpopulation and housing census 2007.

CSA (Central Statistical Authority) (2014): Agricultural Sample Survey, 2013/2014 (2006 E.C.). Report on Area and Production for Major Crops: Private Peasant Holding'Meher' Season. Statistical Bulletin 532, CSA, Addis Ababa, Ethiopia.

Fageria NK, Baligar VC and Jones CA (2011): Growth and Mineral Nutrition of Field Crops. ThirdEdition.Taylor and Francis Group, LLC.,pp 235-256.Boca Raton.

Gomez and Gomez H (1984): Statistical analysis for agricultural research.John Willy and Sons Inc. pp.120-155.

Metson AJ **(**1961): Methods of chemical analysis for soil survey samples. *Newzealand Department of Scientific and Industrial Research, Soil Bureau Bulletin.* pp. 168-175. In:

Hazelton P A, Murphy, B.W., eds. Interpreting soil test results: what do all the, numbers mean?. 2nd Edition. Government Printer,Wellington, New Zealand, New South Wales (NSW) Department of Natural Resources, CSIRO Publishing, Collingwood, Australia.

Olsen S R, Cole C V, Wanatabe F S and Dean L A (1954): Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circular, 939.

Tekalign Tadese (1991): Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa.

Walkley A and Black IA (1934): An examination of the Degtjareff method for determining soil organic matter and proposed chromic acid titration method. Soil Science, 37: 29-38.

Effect of Different Blended Fertilizer Rates on Yield and Yield Components of Bread Wheat (*Triticum aestivum.* L*)* in Central zone of Tigray

Atsede Teklu*, Yonas Gebremaryam and Brhanu Meles

Tigray Agricultural Research Institution, Axum Agricultural Research Center
*Corrospondence: atsedeteklu62@gmail.com

Abstract

A Field experiment was conducted to evaluate the yield and yield responses of bread wheat to different rates of NPSB and NPKSZnB blended fertilizer at Hatsebo and Dibdbo, repectively, during two consecuative main cropping seasons (2017 and 2018) in two locations per Woreda. Seven levels of NPSB (0, 50, 100, 150, 200, 250 and 300 kg ha^{-1}) at Hatsebo and NPKSZnB levels (0, 50, 100, 150, 200, 250 and 300 kg ha^{-1}) at Dibdbo were laid out in Randomized Complete bolck design (RCBD) with three replication. Application of different levels of NPSB and NPKSZnB significantly ($p \leq 0.05$) affected yield and yield components of wheat grown on soil type??at Hatsebo and Dibdibo, repectively. At Dibdbo, the highest grain yield (4163 kg ha^{-1}) was obtainedon plots that received 150 kg ha^{-1} NPKSZnB and biomass (11292 kg ha^{-1}). The lowest grain and strawyields were recorded from unfertilized plots. At Hatsebo, results revealed that the highest biomass and grain yield were recorded from the application of 300 and 250 kg ha^{-1} of NPSB, repectively. The highest MRR (7135.6%) was obtained from application of 150 kg ha^{-}1of NPKSZnB blended fertilizer at Dibdibo and 8404.3% MRR was obtained from application of 100 kg ha^{-1} of NPSB at Hatsebo. Therefore, based on the biological and economic indicators, 150 kg ha^{-1} NPKSZnB and 100 kg ha^{-1} NPSB blended fertilizers could be recommended for Dibdibo and Hatsebo, respectively and for areas with the same soil conditions and agro-ecology for wheat production.

Keywords: NPSB, NPKSZnB, Wheat, Yield

Introduction

In Ethiopia, after tef, maize, and sorghum wheat is the fourth most widely grown crop (FAO, 2015). Wheat grows mostly in the highlands area of Ethiopian, suitable altitudes range between 1500-3000 meter above sea level. . According to CSA (2017/18), out of the total cropped area, 80.71% (10,232,582.23 hectares) was under cereals. Nationally, coverage of wheat is 13.38% in terms of area, and 15.17% in terms of grain production with a yield of 2736 kg ha^{-1}.

In Tigray region out of the 769, 670.80 hectares used to cultivate grain crops, wheat covers 107, 929, 86 hectares with productivity of 1983 kg ha^{-1}. The most limiting factors for low productivity and instability of bread wheat production in Tigray are low soil fertility, soil organic matter depletion and limited knowledge on appropriate rate of blended fertilizer usage and improper agronomic practices affects wheat yield, quality and photosynthetic process.

Soils identified in Tigray are low in soil organic matter, macro and micro nutrients (ATA and MoA 2014). Each of the primary nutrients (N, P and K) is essential in wheat need for life healthy, plant nutrition, and serving a critical role in the growth, development; improve above ground biomass and reproduction of the crop. Without these nutrients, wheat cannot grow to its full potential, provide lower yields, and be more susceptible to disease.

Appropriate rate of the newly recommended blended fertilizers for wheat production were not well investigated in Central zone of Tigray. Therefore, this study was initiated to determine the optimum rate of blended-fertilizer (NPSB and NPKSZnB) on yield and yield components of bread wheat in Central zone of Tigray, Ethiopia.

Materials and Methods

Field experiments were conducted during 2017 and 2018 main cropping seasons at two locations (Hatsebo and Dibdbo). Vertisols of Hatsebo research station is located at 13^0 15' 40.2" N, and 38^0 34’45.8’’ E with an altitude of 2148 meters above sea level. The mean minimum- maximum annual rain fall range 500 between 782.8 mm with the daily average minimum and maximum temperatures of 12.60c and 25.510c, respectively. Dibdbo is located at 13^0 15' 40.2" N, and 38^0 34’45.8’’ E with an altitude of 2148 meter above sea level. The mean minimum- maximum annual rain fall ranges 500 to 782.8 mm with the daily average minimum and maximum temperatures of 12.60c and 25.510c, respectively. The soil texture class for Hatsebo and Dibdibo was clay and loam, respectively. pH was neutral and CEC was very high at both sites. Organic matter was low and total nitrogen (N) and available phosphorous (P) were very low at both sites (Ethiosis 2014).

Seven levels of NPSB (0, 50, 100, 150, 200, 250 and 300 kg ha^{-1}) at Hatsebo and NPKSZnB levels (0, 50, 100, 150, 200, 250 and 300 kg ha^{-1}) at Dibdbo were laid out in Randomized Complete bolck design (RCBD) with three replication. Plot size of 1.2m by 2.5m having 6 rows; spacing between rows, 20 cm; 1 m between replications and 0.5cm between plots were used. Urea fertilizer was applied in split application that was half dose at planting and the remaining at tillering stage. All other input and agronomic practices were carried out uniformly.

Data collection

Data were collected on different agronomic parameters from the four middle rows of each plot, leaving the two rows as borders. Assessments depending on the trait were made both on individual plant and on plot basis.

Phonological traits

Days to 50% heading was observed by counting the number of days from sowing to the time when 50% of the plants head to the tip of panicles. Days to 90% maturity was recorded as the number of days from seedling emergence to the time when 90% of the plants reached physiological maturity. The complete loss of green color of glumes was used as an indicator to determine the date.

Yield and yield components

Plant height (PH) was measured from ground surface to the tip of the panicle at maturity from 5 randomly sampled plants using tape meter (cm). Spike length (SL) was measured from the bottom of the spike to the tip of the spike excluding the awns from five randomly tagged spikes from the net plot. Grain yield was harvested from the eight middle rows of each plot, sun dried and manually threshed separately then grain was weighed by using sensitive electronic balance. The weight biomass from the middle eight rows in each plot was recorded after drying to constant weight. Harvest index was calculated from the ratio of grain yield to biomass yield.

Data analysis

The collected data were analysed using GenStat 18th edition statistical software package and to determine mean separation among treatment effects least significance difference (LSD) at 5% probability level was used.

Economic analysis

The economic analysis was carried out by using the methodology described by CIMMYT (1988) in which prevailing market prices for inputs at planting and for outputs at harvesting were used. All costs and benefits were calculated on hectare basis in Birr. The concepts used in the partial budget analysis were the mean grain yield of each treatment, the gross benefit (GB) ha^{-1} (the mean yield for each treatment) and the field price of fertilizers.). The benefit of straw yield was included in the calculation of the benefit since the farmers of the study area use it for different purposes. Marginal rate of return, which refers to net income obtained by incurring a unit cost of fertilizer and its application, was calculated by dividing the net increase in yield of bread wheat due to the application of each fertilizers rate. The net benefit (NB) was calculated as the difference between the gross field benefit and the total variable (TVC) using the formula

$$NB = GFB - TVC,$$

Where GFB = Gross Field Benefit, TVC = Total Variable Cost

Actual yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same size field. The dominance analysis procedure as described in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested. Any treatment that has higher TVC but net benefits that are less than or equal to the preceding treatment (with lower TVC but higher net benefits) is dominated treatment (marked as “D”). The dominance analysis illustrates that to improve farmers' income, it is important to pay attention to net benefits rather than yields, because higher yields do not necessarily mean high net benefits. The discarded and selected treatments using this technique were referred to as dominated and un dominated treatments, respectively. For each pair of ranked treatments, % marginal rate of return (MRR) was calculated using the formula:

$$\text{MRR }(\%) = \frac{\text{Change in NB (NBb}-\text{NBa)}}{\text{Change in TCV (TVCb}-\text{TVCa)}} \times 100$$

Where NBa = NB with the immediate lower TCV, NBb = NB with the next higher TCV, TVCa = the immediate lower TVC and TVCb = the next highest TCV.

Thus, a MRR of 100% implied a return of one Birr on every Birr spent on the given variable input.

Result and Discussion

Yield and yield components

The combined analysis of variance results showed that application of different rates of NPSB blended fertilizer had significant effect ($P < 0.05$) on yield and yield components of bread wheat at both sites (Table 1 and 2). At Hatsebo, the maximum plant height (84.05 cm) and spike length (10.27cm) were obseved with increasing the rate of NPSB from 50 to 300 kg ha^{-1} which prolonged the day of maturity because the fact that high NPSB rate promoted vigorous vegetative growth. Similarly, at Dibdibo the highest plant height (87.90 cm) and spike length (8.9 cm) were obtained at plots received highest rates of NPKSZnB blended fertilizer which prolonged the day of heading and day of maturity (Table 2).

The higher aboveground biomass weights (10583 and 10000 kg $ha-^{1}$) were obtained from 250 and 300 NPSB kg $ha-^{1}$ of blended fertilizer application, repectively. and the lowest (5667 $kgha-^{1}$) aboveground biomass was recorded from unfertilized plot at Hatsebo. The maximum grain yields (3768 and 3819 kg ha^{-1}) were obtained from 250 and 300kg ha^{-1} NPSB blended fertilizer application, repectively at Hatsebo (Table 1). At Dibdibo, NPKSZnB fertilizer rate application at 150 kg ha^{-1} has delivered a maximum HI (0.37). That means it caused higher grain yield because of storage of dry matter on different parts of the crop which was 150 NPKSZnB kg $ha-^{1}$ blended fertilizer application. This result agrees with the highest grain yield (4163 kg ha^{-1}) which was obtained from 150 kg ha^{-1} NPKSZnB of blended fertilizer application. Conversely, the lowest grains yield (2291 kg ha^{-1}) was obtained in control plot at Dibdibo (Table 2).

Bereket et al (2014) and Melkamu et al (2019) reported that macro and micro nutrients [N, P with Sulfur (S) and Born (B)] fertilizers application can increase plant height, spike length, number of tillers and number of kernel with increasing doses and combination. This result agrees with the finding of Woubshet et al. (2017) who found that application of 150 kg ha-1 NPSB blended fertilizer with compost increased the biomass by 11.5 t ha-1. This may be due to S enhanced the formation of chlorophyll and encouraged vegetative growth and because B might have helped in N absorption.

Table 1. Combined mean performance of NPSB on wheat at Hatsebo

Trt	DH	DM	PH (cm)	PL (cm)	BM(kg ha^{-1})	GY (kg ha^{1})	HI
0	67.0	115.5b	70.2d	8.3b	5500.0d	1791e	0.33c
50 NPSB	67	110.3a	73.50cd	9.60a	6958c	2569d	0.37abc
100 NPSB	64.67	111.2a	78.33bc	9.600a	8750b	3353bc	0.41a
150 NPSB	66.50	111.3a	79ab	9.933a	8625b	3260c	0.38abc
200 NPSB	65.33	111.2a	80.45ab	10.267a	8167b	3201c	0.39ab
250 NPSB	65.33	111.2a	84.05a	10.150a	10583a	3768ab	0.36bc
300 NPSB	64.5	111.0a	81.27ab	10.100a	10000a	3869a	0.39abc
Mean	65.81	111.67	78.11	9.7	8369	3116	0.38
LSD (5 %)	Ns	3.13	5.3	0.7	1207.2	454.7	0.048
CV (%)	3.4	2.4	5.3	6.2	12.3	12.4	10.8

DH: days to heading, DM: days to maturity, PH: plant height, PL: Panicle length, BM: Biomass yield, GY: grain yield, HI: harvest index

Table 2. Combined mean performance of NPKSZnB rate for wheat at Dibdibo

NPKSZnB (kg/ha)	DH	DM	PH (cm)	PL (cm)	BM (kg ha^{-1})	GY (kg ha^{-1})	HI
0	64.75 ab	102.2 a	82.55b	8.2 b	8938 c	2291 d	0.257c
50	66.33 b	103.2 ab	83.17b	8.4 ab	9583 bc	3217 bc	0.35 ab
100	65.33 ab	105.2 c	85.58ab	8.56 ab	9592 bc	3129 c	0.327 b
150	64.17 ab	107.2 d	85.70 ab	8.7 ab	11292 a	4163 a	0.37a
200	63.50 a	105.7 cd	87.20a	8.9 a	11125 ab	3860 abc	0.35ab
250	64.50 ab	105 bc	86.90a	8.48 ab	10850 ab	3790 ab	0.35 ab
300	64.08 ab	105.8 cd	87.67a	8.5 ab	11000 ab	3922 ab	0.34 ab
Mean	64.7	104.9	85.5	8.5	10340	3482	0.33
LSD (5%)	2.02	1.86	3.4	0.51	1550	748.5	0.041
CV(%)	2.7	1.5	3.42	5	12.4	13.7	10.5

DH: days to heading, DM: days to maturity, PH: plant height, PL: Panicle length, BM: Biomass yield, GY: grain yield, HI: harvest index

Economic analysis

Based on economic analysis, the highest marginal rate of return was obtained from the application of 100 kg NPSB ha^{-1} (8404.3%) at Hatsebo and at Dibdibo, the highest marginal rate of retrun was obtained from the application of 150 kg/ha NPKSZnB (7135.7%) (Table 3 and 4).

Table 3. Combined economic analysis in Hatsebo

NPSB (kg/ha)	Adjusted yield (kg/ha)	Gross Field Benefit	Adjusted biological yield (kg/ha)	Gross Field Benefit	Total Gross Field Benefit	Total variable cost (ETB ha^{-1})	Net benefit (ETB ha^{-1})	MRR%
0	1611.9	30626.1	4950	158400	189026.1	0	189026.1	
50	2312.1	43929.9	6262.2	200390.4	244320.3	824.5	243495.8	6606.3
100	3017.7	57336.3	7875	252000	309336.3	1589	307747.3	8404.3
150	2934	55746	7762.5	248400	304146	2383.5	301762.5	D
200	2880.9	54737.1	7350.3	235209.6	289946.7	3088	286858.7	D
250	3391.2	64432.8	9524.7	304790.4	369223.2	3892.5	365330.7	4212.6
300	3482.1	66159.9	9000	288000	354159.9	4657	349502.9	D

D= dominance, MRR= marginal rate of return

Table 4. Combined economic analysis in Dibdibo

NPKSZnB (kg/ha)	Adjusted yield (kg/ha)	Gross Field Benefit	Adjusted biological yield (kg/ha)	Gross Field Benefit	Total Gross Field Benefit	TVC (ETB ha^{-1})	Net benefit (ETB ha^{-1})	MRR%
0	2061.9	39176.1	8044.2	482652	521828.1	0	521828.1	
50	2895.3	55010.7	8624.7	517482	572492.7	824.5	571668.2	6044.88
100	2816.1	53505.9	8632.8	517968	571473.9	1559	569914.9	D
150	3746.7	71187.3	10162.8	609768	680955.3	2323.5	678631.8	7135.66
200	3474	66006	10012.5	600750	666756	3088	663668	D
250	3411	64809	9765	585900	650709	3852.5	646856.5	D
300	3529.8	67066.2	9900	594000	661066.2	4647	656419.2	D

D= dominance, MRR= marginal rate of return

Conclusion and Recommendation

Applications of different levels of NPSB and NPKSZnB significantly ($p \leq 0.05$) affected yield and yield components of wheat at Hatsebo and Dibdibo, repectively. Eventhough, there is some inconsisitencies, grain and biomass yield increased with rates. At Dibdbo, the highest grain (4163 kg ha^{-1}) and biomass (11292 kg ha^{-1}) yields were harvested on plots that received 150 kg ha^{-1} NPKSZnB and the lowest grain and biomass yields were recorded from unfertilized plot. At Hatsebo, results revealed that the highest biomass and grain yields were recorded from the application of 300 and 250 kg ha^{-1} NPSB, repectively. The highest MRR (7135.6%) was obtained from application of 150 kg ha^{-}1of NPKSZnB at Dibdibo and 8404.3% MRR was obtained from application of 100 kg ha^{-1} of NPSB at Hatsebo. Therefore, based on the biological and economic indicators, 150 kg ha^{-1} NPKSZnB and 100 kg ha^{-1} NPSB can be recommended for Dibdibo and Hatsebo, respectively and for areas with the same soil and agro-ecology conditions for wheat production.

Reference

Agricultural Transformation Agency (ATA) and EthioSIS (Ethiopian Soil Information System) team analysis (2014): Soil Fertility Status and Fertilizer Recommendation Atlas for Tigray Regional State, Ethiopia

Arif M, Ali S, Khan A, JanT and Akbar M (2006): Influence of farmyard manure application on various wheat cultivars. Sarhad Journal of Agriculture 22(1):27- 29.

Bereket H., Dawit H., Mehretab H. and Gebremedhin. G. (2014). Effects of Mineral Nitrogen and Phosphorus Fertilizers on Yield and Nutrient Utilization of Bread Wheat on the Sandy Soils of Hawzen Woreda, Northern Ethiopia. Agriculture, Forestry, and Fisheries. 3 (3) 2014, pp 189-198.

CIMMYT (International Maize and Wheat Improvement Center) (1988): From agronomic data to farmer's recommendations: economics training manual. Completely revised edition, CIMMYT, Mexico. D.F. 79 pp.

CSA (Central Statistical Agency). (2017/18): Agricultural sample survey. Vol. I. Report on area and production for major crops (private peasant holdings, meher season). Statistical Bulletin 532, Central Statistical Agency. Addis Ababa, Ethiopia.

FAO (Food and Agriculture Organization), (2000): *Fertilizers and their use 4th ed*. International fertilizer industry association, FAO, Rome, Italy.

Gupta VK, Kumar S, and Singh AK (2004): Yield and quality of wheat (Triticum aestivum L.) as influenced by Sulphur nutrition and weed management. Indian J. Agric. Sci. 74 (5) 254-256.

Mengel K and Kirkby EA (1996): *Principles of Plant Nutrition*. Panimo Publishing Corporation, New Delhi, India.

Melkamu HS, Gashaw M, Wassie H (2019): Effects of different blended fertilizers on yield and yield components of food barley (hordeum vulgare l.) on nitisols at hulla Woreda, southern ethiopia. Acad. Res. J. Agri. Sci. Res. 7(1): 49-56

Tagesse Abera, Ketema Belete and Tamado Tana (2018): Effect of Blended NPS Fertilizer Supplemented with Nitrogen on Yield Components and Yield of Bread Wheat (Triticum aestivum L.*)* Journal of Natural Sciences Research ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online) Vol.8, No.11, 2018

Woubshet D, Selamyihun K and Cherukuri V (2017): Effect of integrated use of lime, blended fertilizer, and compost on productivity, nutrient removal and economics of barley (Hordeum vulgare L.) on acid soils of high lands in West Showa Zone of Ethiopia. Int. J. of Life Sciences, 2017, Vol. 5 (3): 311-322.

Validation of Blended (NPSZn) Fertilizer on Yield and Yield Components of Tef [*Eragrostis Tef (Zuccagni) Trotter*] on Vertisols of Hatsebo, Central Tigray, Ethiopia

Tewolde Berhe*[1], Gebreyohannes Girmay[2], Abrha Kidanemariam[3],
[1]Shire Soil Research Center, Shire, Ethiopia;

[2,] Mekelle University: Department of Land Recourses Management and Environmental Protection, Mekelle, Ethiopia;

[3,]Ethiopian Agricultural Transform Agency: Mekelle, Ethiopia

*Correspondence: tewolde2004@gmail.com

Abstract

An experiment was conducted during the main season of 2017 on farmer's field at Laelay Maichew Woreda with the objectives of validating and determining optimum blended fertilizer rate for tef production of the Woreda. Eight levels of NPSB (0, 25, 50, 100, 150, 200, 250 and 300 kg ha^{-1}) and one recommended NP (100 kg ha^{-1} urea and 100 kg ha^{-1}TSP) were used as treatments. The treatments were laid out in a randomized complete block design (RCBD) with three replications.The blended fertilizer was applied at planting and nitrogen (N) was top dressed in the form of urea in two splits (1/3 at 14 days after planting and 2/3 at 45 days after planting). Surface soil samples were collected before tef sowing and after harvest and analyzed for selected soil properties. Analytical results of the soilsrevealed that total N ~~nitrogen~~, available phosphorus (P), extractable sulfur (S) and boron (B) were low. Application of different blended fertilizer rates significantly affected crop phonology, yield and yield components of tef. Highest mean tef grain yield (2803.09kg ha^{-1}) with the application of 250 kg ha^{-1}NPSB. It had 62.5% increment over control and 33.4% over the recommended NP. The straw yield (7730.5 kg ha^{-1}) was also obtained in plots treated with 250kgha^{-1}blended fertilizer and had 80% and 44.4% yield increment over control and the recommended NP, respectively. Partial budget analysis also revealed highest (1179.5%) marginal rate of return at the rate of 250 kg ha^{-1}NPSB+46 kg N ha^{-1} from which better biomass and economic advantage were obtained. Hence it could be concluded that optimum tef biomass yield could be attained by using 250 kg ha^{-1}NPSB+46 kg N ha^{-1}.

Key words: Tef, blended fertilizer, yield components, NP fertilizer and laelay maichew Woreda

Introduction

Tef (*Eragrostis tef*) is endemic to Ethiopia and its major diversity is found only in Ethiopia. As with several other crops, the location for the domestication of *tef* is at Axum. And it is a very ancient crop in Ethiopia, where domestication took place before the birth of Christ (Seyfu 1997). Vavilov (1951) identified Ethiopia as the center of origin and diversity for*tef*. Hence, Ethiopia is the appropriate and most important center for the collection of *tef* germplasm (Seyfu 1993). When compared with other food crops grown in the country, it is highly-valued by farmers and consumers. This is because of its importance in the national diet of Ethiopia (Hailu et al 2001).

Soil fertility reduction is one of the major challenges to crop production and productivity in Ethiopia (Amsal and Tanner 2001). Soil erosion, over cultivation of farm land, inadequate applications of organic and inorganic fertilizers and decreasing or abandoning of useful traditional soil restoration practices are also some of the causes of declining soil fertility.

Different studies were conducted by various organizations to explore soil fertility status of soils in Ethiopia. The results of these studies revealed that N and P nutrients were the most limiting nutrients in most Ethiopian soils. Subsequently, crop response experiments to fertilizers conducted on-stations and on-farmers' fields revealed that applications of these inputs have appreciablely improved the yields of crops and thus the use of N and P fertilizers to farmers have been recommended (NFSAP 2007). Application of fertilizers containing N and P [urea and diammonium phosphate (DAP)] began in the late 1960s (Wassie and Tekalign 2013) to improve the productivity of the soil. The blanket recommendation [(100 kg DAP (18 N and 46 P_2O_5) and 100 kg urea (46N)] often failed to take into consideration differences in resource endowment (soil type, crop variety,management practices and climate) or make allowances for dramatic changes in input/output price ratio, thereby discouraging farmers from fertilizer application. Moreover, the nutrients in the blanket recommendations are not well balanced and their continued use gradually exhausted soil organic matter (IFPRI 2010).

Depletion of soil nutrients other than N and P could be additional reason for the observed decreases in yield gains (Wassie and Tekalign 2013).The soil fertility mapping project (Ethio SIS 2014) in Ethiopia reported that soils in Ethiopia in addition to N and P are deficient of K, S, Zn, B and Cu. In the study area N, P, S, Zn and B particularly deficient.). Balanced fertilizers containing N, P, S, B, Fe and Zn in blend form have been recommended to solve site specific nutrient deficiencies and thereby increase crop production and productivity (ATA 2014).

In Tigray region, seven soil nutrients [N, P, K ,S, Fe ,Zn and B] are found to be deficient in the soils (EthioSIS 2015). By considering the extent of deficiency of the seven soil nutrients, it was found that the soils require more fertilizer types. The major recommended blended fertilizers for Tigray region were NPS, NPSB, NPSZn, NPSZnB, NPSFeZn and NPSFeZnB. Though K was part of the previous blend fertilizer, recently it was suggested to be applied based on soil test result.

Except the blanket recommendation of N and P, the effect of other fertilizers on yield components, yield, and overall performance of tef are unknown, even though new blended fertilizers such as NPSB (18.7N + 37.4 P_2O_5 + 6.9 S + 0.25 B) (ATA 2014) are currently being used by the farmers in the study area. In addition to this, the amount of N in the blended NPSB is small as compared to the requirement of tef. Thus, there is a need to supplement with nitrogenous fertilizer in the form of urea.

Laelay Maichew is one of the Tigray Woredas which were included in the EthioSIS fertilizer recommendation. Accordingly, the soils in Hatsebo Tabia (farmers' association) exhibit N, P, S and B deficiencies; as a result the NPSB blended fertilizer type is recommended to improve sustainable soil production of the Tabia (EthioSIS 2014). Therefore, this study was conducted to validate and determine the feasible rate of the NPSB blended fertilizer type at Tabia level for optimum *tef* production in the area.

Materials and Methods

Description of the study area

The study was conducted in Central Zone of Tigray Region, at Laelay Maichew Woreda (Hatsebo Tabia), on farmers' field in 2017 main cropping season. Hatsebo Tabia is exactly located (Figure 1) at 14^0 05' 29.22" N and 38^0 46' 48.67" E at an elevation of 2078 meter above sea level. Soils of Hatsebo Tabia are dominantly Vertisols, which covers about 40% of the total area. The soil is low in soil organic matter content N, P, and S, B (ATA and MOA 2014). The area is characterized by mixed crop-livestock farming. Tef *(Eragrostic tef*), wheat (*Triticuma astivum*), fababean (*Vicia faba* L.), sorghum and chickpea (*Cicer arietinum* L.) commonly grow in most parts of the Woreda. The area is characterized by mono modal rainfall distribution pattern and in the cropping season it receives annual rainfall of 783mm. The average annual maximum and minimum temperatures were $28^oC$and 13^oC, respectively (Figure 2 and Figure 3).

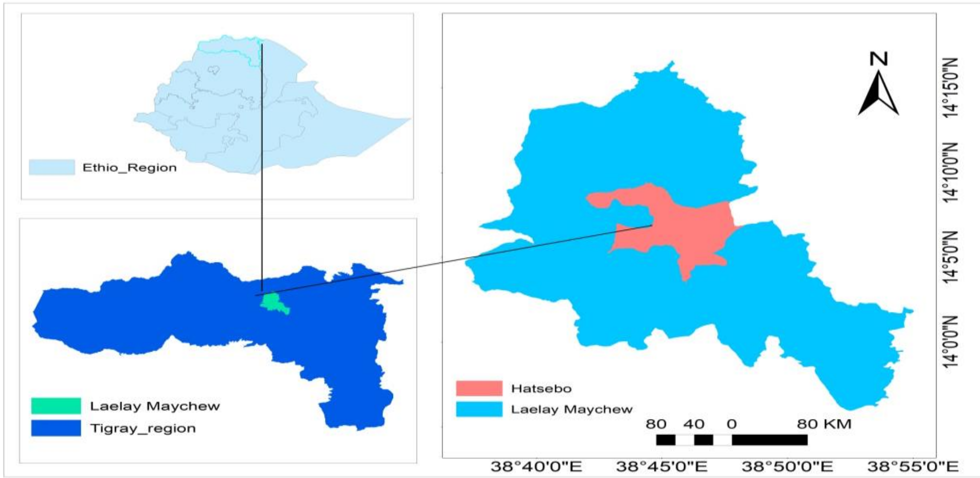

Figure1. Location map of Hatsebo, Laylay Maichew District, Central Tigrai, Ethiopia

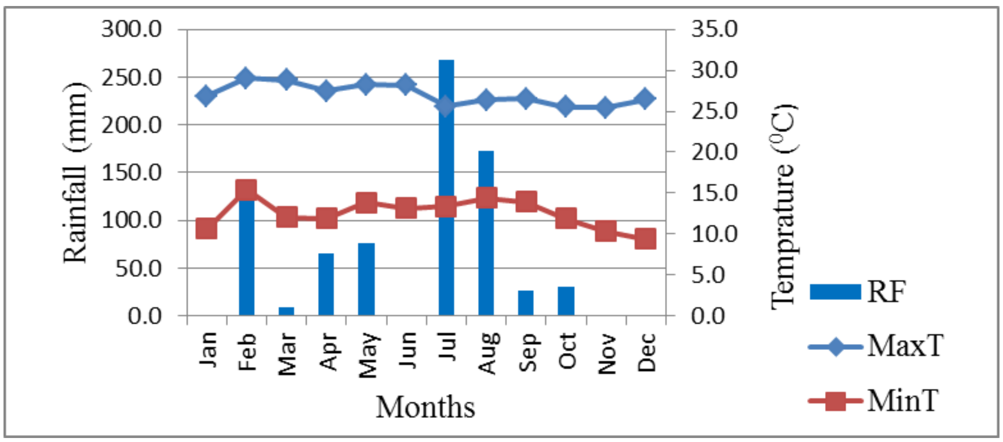

Figure 2. Rainfall, maximum and minimum temperatures in the study area during the cropping season

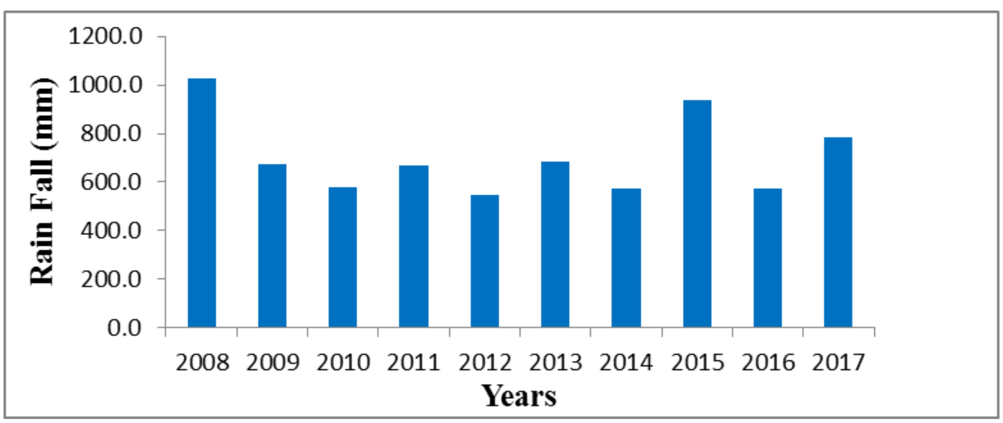

Figure 3. Ten years annual rainfall recorded in the study area

Experimental procedures, layout and treatments

The experiment was laid out in randomized complete block design (RCBD) with nine treatments, eight levels of NPSB (0, 25, 50, 100, 150, 200, 250, 300 kg NPSB ha^{-1}) and blanket Recommended NP at rate of 64 kg $Nha^{-1}$and 46 kg P_2O_5 ha^{-1}). The plot size was 3 m x 3 m with three replications. The distance between replication and plots were 1m and 0.5m, respectively. The plots in each replication were represented randomly for each treatment.

The eight blended (NPSB) fertilizer rates were compared to each other and with the blanket recommended NP fertilizer to determine one best fitted rate. Since, nitrogen is the most limiting factor for plant growth and found in a very low amount in the blended fertilizer, 46kg$Nha^{-1}$was top dressed in two split (1/3 at 14 days after planting and 2/3 at 45 days after planting) for all treatments except for control and recommended NP but blended fertilizers was applied at sowing time. The test crop was also planted in rows with 1m*0.5m*20 cm spacing between blocks, plots and row plants, respectively. Quncho variety was tested at seed rate of 5kgha^{-1}. All crop management practices were applied as per the recommendation for the tef.

Soil sampling and preparation

One fresh profile with 1.5 m width by 1.5 m length and 2 m depth were opened for the experimental field. Samples were taken from all identified layers for characterization of selected physical and chemical properties according to FAO guidelines (FAO, 2014).One disturbed composite soil sample was collected at 0-20 cm depth based on zigzag sampling method before planting to assess what the soil had and 27 representative soil samples were collected after harvest from the total of 27 experimental plots using zigzag sampling method from 0-20 cm depth. Soils after harvested were analyzed for TN, available P, extractable S and Extractable B.

The collected samples were properly labeled, packed and transported to the soil laboratory in Mekelle Soil Research Center. The surface and profile soil samples collected from the experimental field were air dried and crashed and allowed to pass through 2 mm sieve and for further analysis for total nitrogen (TN) and organic carbon (OC) allowed to pass through 0.5 mm sieve (FAO 2008).

Soil analysis

Soil samples before planting were analyzed of particle size distribution, bulk density, soil reaction (pH), electrical conductivity (EC), OC, TN, available ($P_{av)}$, available (S_{ext}) B_{ext} and

Cation Exchange Capacity (CEC) and the samples were analyzed after harvest for T N, OC, available P, extractable S and B, following the standard procedure.

Data collection and measurements

Grain yield data for each plot was recorded by weighing the grain harvested from each net plot after trashing/separating the seed from its straw and after the seeds were thought to be completely dried and finally the result was converted to quintals per hectare. Straw yield was calculated by subtracting grain yield from the total above ground biomass from each net plot. After that it was converted to quintals per hectare.

Data analysis

The collected agronomic data were subjected to statistical analysis like analysis of variance. Analysis of variance (ANOVA) was performed using Statistical Analysis System (SAS) version 9.1 (SAS 2009) statistical software programs. Significant differences between and among treatment means were assessed using the least significant difference (LSD) at 0.05 level of probability (Gomez and Gomez 1984).

Economic analysis

Economic analysis was performed using partial budget analysis to investigate the economic feasibility of the treatments which were tested in the experiment. Marginal rate of return (MRR) was calculated as the change in net revenue (NR) divided by the change in total variable cost (TVC) of the successive net revenue and total variable cost levels [International Maize and Wheat Improvement Center (CIMMYT), 1988]. Labor costs were calculated by assuming 60 ETB per day per person and revenue was calculated by assuming 23.8 ETB kg^{-1} of *tef* grain yield, 3.1 ETB $kg^{-1}$for straw yield and costs of fertilizers (1457.20 ETB for 100 kg of NPSB, 1625.25 ETB for 100 kg of NPS, 1251.65 ETB for 100 kg of urea, 1337.89 ETB for 100 kg of borax and 1667.10 ETB for 100 kg of TSP) was calculated based on the last year price. According to this manual, experimental yields are often higher than the yields that farmers could expect using the same treatments; hence in economic calculations researchers have judged that farmers using the same technologies would obtain yields adjusted by 10% lower than those obtained by the researchers if the experiments are planted on representative farmers' fields, (CIMMYT, 1988).

Results and Discussion

Soil characteristics of the study area

Soil physical properties

Particle size analysis, with sand (16%), silt (26%) and clay (58%), indicates that clay particles dominated the soil and its textural class was categorized as clay (Table 3). Vertisols are characterized by high clay content with swelling and shrinking characteristics (FAO 2014). Bulk density of the experimental soil was also found to be 1.34 g cm^{-3} before sowing *tef* (Table 1).The soil of the study area was not restricting plant root development and good for cereal crop production. Soil moisture content of the area was found 21% (Table 3). Total porosity was calculated as 0.49% and in relation to plant growth the critical limit of air-filled porosity is 0.10 or 10%; therefore the study area was good soil (Lal and Shukla 2004). Generally, according to Lal and Shukla (2004) the normal range of soil physical properties in relation to plant growth are bulk density 0.7-1.8 gcm^{-3}, porosity 0.3-0.7 m^3m^{-3}, volumetric soil moisture content 0-70%. Therefore, soil of the study area was within the range of good soil for cropping.

Soil chemical properties

The soil pH before sowing (Table 1) was neutral (Tekalign 1991). According to Landon (1991), soils having a pH value in the range 5.5 to 7.5 are considered suitable for most agricultural crops. Therefore, the soil pH values recorded in the study area of the present study agrees with these findings. The electrical conductivity was 0.41 dS m^{-1} before sowing indicating a non-saline soil (Marx et al 1999). Generally, the EC value measured at the study area indicated the concentration of soluble salts below the levels at which growth and productivity of most agricultural crops are affected due to soil salinity Landon (1991).

The OC and TN in soil before sowing were 0.64% and 0.091%, respectively (Table 1). According to Tekalign (1991), OC and TN of the study area were rated as low and very low, respectively. Low TN content of the soil could also be attributed to the low soil OC content. The C: N ratio of the study area was 7 and this was good for mineralization of nutrients available for plant growth. C: N ratio less than 25:1 goes through mineralization (Mohanty et al 2011).

There was low available P before sowing (4.17 mg kg^{-1}) which was rated as very low (Olsen et al 1954). Therefore the area demands high amount of available P from applied NPSB fertilizers.

The value for extractable S and extractable B before sowing were 4.28 mg kg^{-1} 0.319 mg kg^{-1}, respectively (Table 1). Soil extractable S was found to be low as rating suggested by Hazelton and Murphy (2007). The low soil sulfur in the study area may be due to its low OC content as reported by Shaun et al (2012) who indicated that the lower organic matter contents cause more likely S decreasing. Similar to N and P, S was also the limiting nutrient for optimum crop production on soils of the study site (EthioSIS 2015). Based on the rating suggested by Berger and Truog (1939) the experimental area was also deficient in B. The CEC of the soil before sowing was 56.4 cmol (+) kg^{-1}. The soil CEC was found to be very high (Landon 1991). High CEC of the soil should be due to higher clay content of the soil as the soil OC content was found very low for the study site.

Table 1. Soil physico- chemical properties of the experimental area (sampled at depth of 0-20cm)

Para m-eters	BD (gcm^{3})	Sand (%)	Silt (%)	Clay (%)	Texture class	pH (H_2O)	EC (dS m^{-1})	OC (%)	TN (%)	P_{av} (mg kg^{-1})	S_{ext} (mg kg^{-1})	B_{ext} (mg kg^{-1})	CEC cmol(+) kg^{-1}
Value	1.34	16	26	58	clayey	7.1	0.41	0.64	0.091	4.17	4.28	0.319	56.4

*: BD = bulk density, pH= power of hydrogen, EC= electrical conductivity, OC= organic carbon, TN= total nitrogen, P_{av}= available phosphorus, S_{ext}= extractable sulfur, B_{ext}= extractable boron and CEC= cation exchange capacity

Total N content after harvest was highly influenced by the applied levels of the fertilizers. The higher N was obtained at the higher treatment levels (Table 2) and the residual amount of TN was rated as low (Tekalign 1991). This might be due to the logging effect and decreased uptake beyond 250 kg NPSB ha^{-1}.

There were highly significant differences in available P after harvest due to differences in the treatments. The higher available P_{av} (8.13 mg kg^{-1}) was obtained at 300 kg ha^{-1} NPSB and this was higher than the amount of P before sowing (Table 2). This was due to residual effect of P applied within the blended fertilizer and since P has low mobility and leaching, it remains in higher amount. According Olsen et al (1954) range of available P after harvest was rated as medium.

The value for extractable S was also highly influenced by the levels of fertilizer applied and the higher S (4.61 mg kg^{-1}) was obtained at higher level (Table 2). Soil S_{ext} was found to be low as rating suggested by Hazelton and Murphy (2007). The low soil sulfur in the study area may be due to its low OC content as reported by Shaun et al (2012) who indicated that the lower organic matter contents caused more likely S decreasing. Similar to N and P, S was also the limiting nutrient for optimum crop production on soils of the study site (EthioSIS 2015). The extractable B (B_{ext}) after harvesting was 0.34 mg kg^{-1} (Table 2). Based on the rating suggested by Berger and Truog (1939), the experimental area had low B content.

Table 2. Soil chemical properties of the study site after harvest

Treatments (NPSB+N) (kg ha^{-1})*	TN	P_{av}	S_{ext}	B_{ext}
0-0	0.041^{cd}	2.597^{ed}	0.708^{g}	0.050^{c}
Rec.NP (46-46)	0.060^{cb}	2.427^{e}	0.940^{fg}	0.090^{c}
25-46	0.020^{d}	3.193^{ed}	1.200^{fge}	0.210^{b}
50-46	0.025^{d}	3.100^{ed}	1.727^{fde}	0.270^{ba}
100-46	0.061^{cb}	3.120^{ed}	2.037^{cde}	0.290^{ba}
150-46	0.075^{b}	4.100^{cd}	2.457^{cd}	0.300^{ba}
200-46	0.082^{b}	5.500^{cb}	2.747^{cb}	0.310^{a}
250-46	0.111^{a}	6.133^{b}	3.600^{b}	0.340^{a}
300-46	0.124^{a}	8.100^{a}	4.610^{a}	0.334^{a}
$LSD_{(0.05)}$	0.024	1.645	0.931	0.097
P-value	<.0001	<.0001	<.0001	<.0001
CV (%)	12.43	13.52	14.63	13.98

*: TN= total nitrogen, P_{av}= available phosphorus, S_{ext}= extractable sulfur and B_{ext}= extractable boron

Effects of blended fertilizer rates on growth parameters

Days to 50% heading and 90% physical maturity

The effects of blended (NPSB) fertilizer rates on days to panicle emergence of tef were highly significant ($P<0.01$). The delayed days to 50% panicle emergence (66.33 days) was recorded on the control plot, while the promoted day (56 days) was recorded for the highest rate of 300 kg blended NPSB ha^{-1} with 46 kg N ha^{-1} fertilizers (Table 3).

The hastened panicle emergence at highest rates of NPSB could be due to early establishment, rapid growth and development of crop. The application of supplementary N hastened the days to heading possibly because the tef plants were able to take up sufficient N from the soil and also because uptake of N may have enhanced the uptake of other nutrients such as P and S which might have enhanced growth and development of the crop plant. This result is consistent with the result of Temesgen (2001) who reported that sufficient N supply promoted the uptake of other nutrients, enhancing growth and development of tef. This result was also in agreement with that of Getahun et al (2018) who reported that the heading of tef plants was accelerated as NP rate increased from zero to 69 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1} fertilizer applications.

This result is in contrast with Legesse (2004) who reported that N fertilization at the rate of 46 kg N ha^{-1} significantly delayed the heading stage of tef by five days as compared to the control.

Similarly, Abraha (2013) reported that the application of N at the rate of 46 kg ha^{-1} delayed days to heading of tef over the control.

Table 3. Days to 50% heading and days to 90% physiological maturity of tef as influenced by Blended fertilizer (NPSZnB) rate

Treatments (NPSB-N) (kg ha^{-1})	DH (days)	DPM (days)
0-0	66.33a	113.67a
Rec.NP(46-46)	60.00bcd	107.33cd
25-46	61.00b	109.67b
50-46	60.33bc	108.33bc
100-46	58.67cde	107.33cd
150-46	58.00def	107.67cd
200-46	57.33ef	106.67cd
250-46	57.00ef	106.67cd
300-46	56.00f	106.33d
$LSD_{(0.05)}$	59.41	108.19
P-value	<.0001	<.0001
CV (%)	1.30	0.62

Where; DH= Days to 50% Heading, DPM= Days to 90% physiological maturity, LSD= Least Significant Difference, CV= Coefficient of Variance and NS = non significant; means followed by the same letters are not significantly different ($P \leq 0.05$) according to LSD Tests.

Physical maturity (90%) also showed the same trend, there was highly significant difference among the treatments. The late maturity (113.67 days) was obtained at the control plot, while the hastened physical maturity (106.33 days) was recorded at the highest fertilizer rate of 3000 kg ha^{-1} NPSB (Table 3).

The enhanced maturity with the application of blended fertilizer could be due to the presence of balanced fertilizer in the blended fertilizer, as the level of fertilizer increases physical maturity hastened. The result of the present study is contrary with the result of Abraha (2013) who reported that as the rate of N increased from 0 to 69 kg N ha^{-1}, days to maturity of tef was significantly delayed.

Plant height and head length

The analysis of variance showed a highly significant difference among the treatments ($P \leq 0.05$). The highest plant height (120.67 cm) was observed from the plot treated with 250 kg ha^{-1} NPSB rate, while the shortest plant height (84.87 cm) was obtained from control plot (Table 4). The highest plant height obtained at the higher blended fertilizer levels might be due to the vital role of N applied for elongation and vegetative growth. This result was in agreement with the research findings of Okubay et al (2014) where the maximum plant height (112.33 cm) was obtained from the application of the highest rate (69 kg N ha^{-1}) whereas the lowest plant height was obtained from the control plot of the tef crop. It is also in line with the report of Wakene et al (2014) who stated that plant height of barley increased with increasing rates of N from 0 to 69 kg ha^{-1}. However, in contrast with this finding, increasing the rate of NPSB application from 0 to 150 kg ha^{-1} did not significantly affect the height of tef plants.

Table 4. Plant height and panicle length of tef as influenced by Blended Fertilizer (NPSZnB) rate

Treatments (NPSB-N) (kg ha^{-1})	PH (cm)	HL (cm)
0-0	84.87d	34.47b
Rec.NP(46-46)	109.80bc	43.80a
25-46	104.67c	44.60a
50-46	113.60ab	44.00a
100-46	114.07ab	44.20a
150-46	110.40bc	43.33a
200-46	115.40ab	45.20a
250-46	120.67a	45.67a
300-46	116.13ab	43.53a
$LSD_{(0.05)}$	109.96	43.20
P-value	<.0001	0.0023
CV (%)	2.71	6.06

Where; PH= Plant height, PL= Panicle Length, LSD= Least Significant Difference and CV= Coefficient of Variance; means followed by the same letters are not significantly different ($P \leq 0.05$) according to LSD Tests.

Panicle length showed no any statistical difference between the treatments except with control plot. Accordingly, the plots treated with 250 kg ha^{-1} NPSB had the highest panicle height (45.67 cm) but plot which received no fertilizer gave the lowest panicle length (Table 4).

Similar to plant height, panicle length also increased with increasing N fertilizer rate. In line with this result, Getahun et al (2018) reported that the longest panicle length (39.9 cm) was obtained from the application of 69 kg N ha^{-1} while the shortest (31.6 cm) was recorded from the control. Thus, increasing N from 0 to 69 kg N ha^{-1} increased panicle length by about 26.3%, compared to the control.

Effects of blended fertilizer rates on yield components

The analysis of variance showed no significant differences except with the control plot on both total tillering and productive tillering. The highest number of total tillers (1593 plants) was obtained with the application of blended fertilizer 300 kg NPSB ha^{-1}, and productive tillers (12.67 plants) were obtained at the plot that received 250 kg NPSB ha^{-1}. While the lowest number of total and productive tillers were obtained from the unfertilized plots (Table5). The increased total tillers on plots treated with blended fertilizer than in the unfertilized plot might be due to the profound effect of balanced nutrition for root development and branches. This result is in agreement with that of Brhan (2012) who reported that application of blended fertilizer (69 kg N ha^{-1} + 46 kg P_2O_5 + 22 kg S ha-1 + 0.3 kg Zn ha^{-1}) brought significant increase in total tillers (15 tillers per plant) of tef as compared to 5 tillers per plant of unfertilized plot.

Table 5. Tillering capacity per plant of tef as influenced by NPSB fertilizer rate

Trt (NPSB-N) (kg ha^{-1})	NT	NET
0-0	8.87c	5.47c
Rec.NP(46-46)	13.93ab	10.80ab
25-46	13.60abc	10.20ab
50-46	13.07abc	10.07ab
100-46	10.40bc	7.67bc
150-46	15.27ab	11.87a
200-46	15.20ab	12.40a
250-46	15.47a	12.67a
300-46	15.93a	12.47a
LSD$_{(0.05)}$	13.53	10.40
P-value	0.0009	<.0001
CV (%)	12.89	12.23

Where; NT= Number of tillers per plot, NET= Number of effective tillers, LSD= Least significant difference and CV= Coefficient of Variance; means followed by the same letters are not significantly different ($P \leq 0.05$) according to LSD Tests

Grain yield

Grain yield of *tef* was highly significantly ($P \leq 0.05$) influenced by rates of blended fertilizer applied. The highest grain yield (2803.09 kg ha^{-1}) was recorded as a result of 250 kg ha^{-1} of NPSB and the lowest yield (1051.11 kg ha^{-1}) was obtained from the control plot (Table 6).The maximum yield had 62.5% yield increment over control and 33.4% over the blanket recommendation. The highest grain yield was higher than the national average yield (16.64 quintal ha^{-1}) (CSA 2017) and plot treated with the recommended NP. This could be due to the combined effect of nutrients like N, P, S and B in blended fertilizer which might have enhanced growth and development of crop compared to the rest of the treatments. It was also the improved number of effective tillers per plant (Table 5) and higher panicle length (Table 4) obtained at the plot treated with 250 kg NPSB ha^{-1} that might have contributed more to the cumulative effect towards enhanced yield.

The response of *tef* to blended fertilizer rates didn't show consistent variation among treatments but it indicated the importance of the macro and micronutrients.In line with this study, Lemlem (2012) reported that application of blended fertilizer and urea significantly increased the N, P, K, Zn, Mg and S concentration of *tef* grains and increased grain yield in Regosols and Vertisols.In agreement with this result, Jarvan et al (2012) reported that the addition of 100 kg N ha^{-1} with 10 kg S ha^{-1} to winter wheat gave yield of 5.88 t ha^{-1} while it gave 5.73 t ha^{-1} when 100 kg N ha^{-1} with 6 kg ha^{-1} S. On the other hand, Brhan (2012) reported that treatments that received blended fertilizers (69 kg N ha^{-1} + 46 kg P_2O_5 + 22 kg S ha^{-1} + 0.3 kg Zn ha^{-1}) under row planting of tef gave 4155 kg ha^{-1} and increased 30% and 378% over treatments that receive urea and DAP under row planting and control plots, respectively. Feyera et al (2014) also reported that application of blend fertilizer levels improved the agronomic performance, as a result enhanced nutrient use efficiency of *tef* which increased the grain productivity. Decline in grain yield might be related to the reductions observed in the content of the panicle (filled seed per panicle) with increased N rates in the blended fertilizer and consequently decreased grain yield ha^{-1}.This result is consistent with that of Reinke et al (1994) who noted that where the grain yield response is negative, yield reduction is primarily caused by a reduction in the proportion of the number of filled spikelets per panicle.

Table 6. Grain and straw yield of *tef* as influenced by NPSB

Treatments (NPSB-N)(kg ha^{-1})*	GY (kg ha^{-1})	SY (kg ha^{-1})	LI (%)	HI (%)
0-0	1051.11^{e}	1549.7^{f}	0.04f	40.48^{a}
Rec.NP(46-46)	1867.62^{c}	4299.5^{d}	26.20c	30.27^{b}
25-46	1339.17^{d}	3328.6^{d}	6.80e	28.69^{b}
50-46	1631.64^{c}	4068.8^{d}	11.00ed	28.66^{b}
100-46	2288.10^{b}	5879.3^{c}	13.27d	28.05^{b}
150-46	2356.37^{b}	6044.3^{c}	25.00c	28.03^{b}
200-46	2484.75^{b}	6558.9^{c}	47.03b	27.47^{bc}
250-46	2803.09^{a}	7730.5^{a}	51.80ab	26.61^{bc}
300-46	2393.39^{b}	7633.7^{a}	57.07a	23.87^{bc}
LSD$_{(0.05)}$	247.44	438.94	26.47	4.14
P-value	<.0001	<.0001	<.0001	<.0001
CV (%)	4.273347	2.932170	7.57	4.97

*:GY= grain yield, SY= straw yield, LI = Lodging index, HI = harvest index, variable means followed by the same letters are not significantly different (*p≤0.05*) according to LSD tests

Straw yield

The analysis of variance showed that straw yield was highly significantly affected ($P \leq 0.05$) by different blended fertilizer rates. The highest straw yield was obtained in response to applying 250 kg ha^{-1} (Table 6). Thus, straw yield obtained from plots applied with 250 kg NPSB ha^{-1} was higher by about 80 and 44.4% as compared to the *tef* straw yield obtained in response to unfertilized plot and the plot received the blanket fertilizer recommendation(46 N and 46 P_2O_5) kg ha^{-1}. Increasing the rates of blended application from 0 kg ha^{-1} to 250 kg ha^{-1} significantly enhanced *tef* straw yield. This might be due to plants grown on plots treated with higher rate of N for their vegetative growth, higher P for their good root development, higher level of S for high number of tillering and B for its higher cell division and contributed to increasing the total number of tillers per plant and influence the straw yield.

The plots treated with blend fertilizer scored higher straw yield may be due to the contributed combined effect of balanced fertilization. The highest plant height and tillers also had great contribution to higher straw yield. Fageria et al (2011) also indicated that application of S enhanced the photosynthetic assimilation of N in crops. Hence, application of N and S increased the net photosynthetic rate which in turn increased the dry matter as 90% of dry weight considered to be derived from products formed during photosynthesis. Abdo (2009) and Abraha (2013) respectively reported highest straw yield of durum wheat and *tef* in response to N applied at higher rate up to 69 kg N ha^{-1}. In agreement with this result, Haftom et al. (2009) found increasing biomass with the increasing rate of N with the highest biomass yield (4724.07 kg ha^{-1}) of tef in response to the application of 69 kg N ha^{-1}.

Lodging Index

Logging index of *tef* was highly significantly ($P \leq 0.05$) affected by different rates of the blended fertilizer. Increasing rate of fertilizer rate increased lodging index of *tef* crop across all the fertilizer levels. The lowest lodging index was observed on plants grown under rate of 0 kg ha^{-1} (unfertilized plot) and the higher lodging index was observed under plot received 300 kg ha^{-1} NPSB (Table 6). The lodging index of plants grown on plots treated with 300 kg ha^{-1} NPSB exceeded the lodging index of those grown on plots treated with 0 kg ha^{-1} by 99.3% meaning there was higher lodging problem with the application of higher fertilizer rates.Crop lodging with increased fertilizer rate could be due to the profound effect of high N supply within the NPSB on enhancing vegetative growth thereby leading to bending of the weak stem of the plant due to the sheer load of the canopy. These results therefore, revealed that increasing the rate of N within the blended fertilizer leads to the detrimental effect of crop losses due to lodging. Seyfu (1993) reported that lodging in cereals is considered to be caused by high rate of N fertilizer application.

Harvest index

The analysis of variance revealed significant ($P<0.0001$) difference among the treatments in harvest index of tef and as the level of the fertilizer increased, the harvest index decreased.

Therefore the highest index was obtained at control plot (Table 6). In line with this; Abraha (2013) reported that the highest *tef* HI was obtained on lower rate of fertilizer application.

Partial budget analysis

As indicated in Table 7, the highest net benefit of 76,356.2 Birr ha^{-1} with marginal rate of return (MRR) of 1179.5% was obtained in response to application of 250 kg blended NPSB ha^{-1} top dressed with 46 kg N ha^{-1}. However, the highest marginal rate of return (2323.9%) was obtained in response to 100 kg ha^{-1} NPSB for the Woreda. According to the manual for economic analysis of CIMMYT (1988), the recommendation is not necessarily based on the treatment with the highest marginal rate of return. For farmers who use no fertilizer, investing in100 kg ha^{-1} NPSB gives a very high rate of return, but if farmers stopped there, they would miss the opportunity for further earnings, at an attractive rate of return, by investing an additional fertilizer. Farmers continue to invest as long as the returns to each extra unit invested (measured by the marginal rate of return) are higher than the cost of the extra unit invested (measured by the minimum acceptable rate of return). Thus, applications of 250 kg blended NPSB ha^{-1} with 46 kg N ha^{-1} is economically beneficial as compared to the other treatments in the study area because the highest net benefit and the marginal rate of return were above the minimum level (100%).

Table 7. Partial budget analysis of blended fertilizer rates for grain and straw yield of *tef*

TRT	Grain Yield		Straw Yield		Gross Revenue (GR) Sum (1+2)	Costs			Net Revenue [TR-TVC]	MRR (ratio) [(Rt2-Rt1)/(Ct2-Ct1)]	MRR (%)
	Adj. yield	Total Revenue (1)	Adj. yield	Total Revenue (2)		fertilizer cost [Birr]	Transport and Application cost [Birr]	Total variable cost (TVC) [Birr]			
Control (0,0)	946.0	22514.8	1394.7	4323.6	26838.4	0	0	0	26838.4	0.00	0.0
25NPSB + 46N	1205.3	28686.1	2995.7	9286.7	37972.8	1615.95	60	1675.95	36296.8	5.64	564.4
50NPSB + 46N	1468.4	34947.9	3661.9	11351.9	46299.8	1980.25	120	2100.25	44199.5	18.63	1862.5
100NPSB + 46N	2059.3	49011.3	5291.4	16403.3	65414.6	2708.85	180	2888.85	62525.8	23.24	2323.9
Rec.NP(100:100)	1680.8	40003.0	3869.6	11995.8	51998.8	2918.75	180	3098.75	48900.0	D	D
150NPSB + 46N	2120.7	50472.7	5439.9	16863.7	67336.4	3437.45	240	3677.45	63658.9	1.44	144.0
200NPSB + 46N	2236.2	53221.6	5903.0	18299.3	71520.9	4166.05	300	4466.05	67054.9	4.31	430.6
250NPSB + 46N	2522.8	60042.6	6957.5	21568.3	81610.9	4894.65	360	5254.65	76356.2	11.79	1179.5
300NPSB + 46N	2154.1	51267.6	6870.3	21297.9	72565.5	5623.25	420	6043.25	66522.3	D	D

Where: Adj.= adjusted MRR= marginal rate of return, Rt1= net revenue of treatment one, Rt2 = net revenue of treatment two, Ct1 = total cost of treatment one and Ct2 = total cost of treatment two.
NB: Cost of 1 kg tef = 23.80 birr and Cost of 1kg straw 3.10 birr

Conclusion and Recommendation

The study revealed the potential advantages of blended fertilizer rates (NPSB) over the N and P blanket recommendation for *tef* production on vertisols of central zone, Lailay maichew Woreda. Depending on the results of this study, the following conclusions can be forwarded. Based on the soil analytical results, soil status of the study area before planting were 0.09%, 4.17 mg kg^{-1}, 4.28 mg kg^{-1} and 0.319 mg kg^{-1} for TN, available P, extractable S and extractable B, respectively. These results are rated as low therefore, the area is deficient in these plant nutrients.

The highest grain yield (2803.09 kg ha^{-1}) was recorded at the application of 250 kg ha^{-1}NPSB and with increment of 62.5% over control and of 33.4% over recommend NP (blanket recommendation). Similarly the highest straw yield (7730.5 kg ha^{-1}) was recorded at the application rate of 250 kg ha^{-1}NPSB with yield increment of 80% over control and 44.4%over the recommend NP. The lowest yield was recorded on control plot in all physical and yield parameters.

Generally, the overall yield performance of the crop was satisfactory under blended fertilization. The highest grain yield (2803.09 kg ha^{-1}) obtained at 250 kg ha^{-1} under blended fertilizer was higher than the national average yield (1664 kg ha^{-1}) and the highest straw yield (7730.5 kg ha^{-1}) obtained at 250 kg ha^{-1} where blended fertilizer was very promising for animal fating.

Based on the results of the study, the following recommendations were forwarded.

- Blended fertilizer (NPSB) at a rate of 250 kg ha^{-1} NPSB + 46 kg N ha^{-1} for *tef* production on Vertisol at Hatsebo should be used as a bench mark.
- Impacts of the additional nutrients (sulfur and boron) in the blended fertilizer seem more significantly valued in increasing the biomass production of *tef*. Thus, further study across different years, locations and soils is very important.
- Additional studies are also needed on the impact of these blended fertilizers on grain quality of *tef*.

References

Abdo Woyema (2009): Effect of different rates of nitrogen fertilizer on yield, yield related traits and Quality of durum wheat (*Triticum turgidum* L.var durum). M.Sc. Thesis, Haramaya University, Haramaya, Ethiopia.

Abraha Arefaine (2013): Effects of Rates and Time of Nitrogen Fertilizer Application on Yield and Yield Components of Tef [Eragrostis tef (Zucc.) Trotter] in Habro Woreda, Eastern Ethiopia. M.Sc. Thesis, Haramaya University, Haramaya, Ethiopia.

Amsal T and Tanner D (2001): Effect of fertilizer application on N and P uptake, recovery and use efficiency of bread wheat grown on two soil types in central Ethiopia. Ethiopian Journal of Natural Resources. 3(2): 219-244.

ATA (Agricultural Transformation Agency) (2014): Soil Fertility Status and Fertilizer Recommendation Atlas for Tigray Regional State; Ethiopia July 2014.

Berger KC and Truog E (1939): Boron determination in soils and plants. *Ind .Eng. Anal. Ed.11*:540-545

Brhan Abayu. (2012). Agronomic and Economic Effects of Blended Fertilizers Under Planting Method On Yield And Yield Components of Tef: M.Sc Thesis, Mekelle University, Mekelle, Ethiopia.

Caldicott JJB. and Nuttall AM (1979): A method for the assessment of lodging in crops. *Netherland Journal of Agricultural Botany*, (15):88-91.

CIMMYT (International Center for Maize and Wheat Research) (1988): From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition, *Mexico. D.F conference held at International Livestock Centre for Africa (ILCA),* 31 August - 4 September 1987.

CSA (Central Statistical Agency) (2016): Agricultural Sample Survey for the 2015/2016 crop season. Volume II Report on Area and production of Crops for Private Peasant Holdings (Meher Season) Statistical Bulletin 446. FDRE/CSA, Addis Ababa, Ethiopia.

CSA (Central statistical agency) (2017): Agricultural sample survey for the 2016/2017 crop season. Volume I Report on Area and production of major Crops private peasant holdings, meher season (September – December 2014). Statistical bulletin, FDRE/CSA, Addis Ababa, Ethiopia.

Ethio-SIS (Ethiopian Soil Information System) (2014): Soil Analysis Report. Agricultural Transformation Agency (Unpublished).

EthioSIS (Ethiopian soil information system) (2015): http://www.ata.gov.et/highlighted-deliverables/ethiopian-soil-information-system-ethiosis.

Fageria NK Baligar VC and Jones CA (2011): Growth and Mineral Nutrition of Field Crops.3rdEdn., Taylor &Francis Group, New York, 530 p.

FAO (Food and Agricultural Organization) (2008): Guide to laboratory establishment for plant nutrient analysis, fertilizer and plant nutrition bulletin 19 Rome.

FAO (Food and Agricultural Organization). (2008). Guide to laboratory establishment for plant nutrient analysis, fertilizer and plant nutrition bulletin 19 Rome.

FAO. (2014): Guidelines for soil description. 5th edition. Rome.

Getahun Dereje, Dereje Alemu, Tigist Adisu and Bekele Anbessa (2018): Response of Yield and Yield Components of Tef [Eragrostis tef (Zucc.) Trotter] to Optimum Rates of Nitrogen and Phosphorus Fertilizer Rate Application in Assosa Zone, Benishangul Gumuz Region. Ethiopian. Journal. Agricultural. Science., 28(1) 8194

Gomez and Gomez H (1984): *Statistical analysis for agricultural research*. John Willy and Sons Inc. pp.120-155.

Haftom Gebretsadik, Mitiku Haile and Yamoah CH (2009): Tillage frequency, soil compaction and N-fertilizer rate effects on yield of tef [Eragrostis tef (Zucc.) Trotter]. Ethiopia. Journal of Science, 1(1): 82-94.

Hailu Tefera and Seifu Ketema (2001): Production and Importance of Tef in Ethiopian Agriculture. In: Hailu Tefera, Getachew Belay and Mark Sorrells (eds).Narrowing the Rift: Tef Research and

Development. Proceedings of the International Workshop on Tef Genetics and Improvement, 16-19 October 2000, Debre Zeit, Ethiopia.
Hazelton P and Murphy B (2007): Interpreting soil test results: What do all the numbers mean? 2nd Edition. CSIRO Publishing. 152p.
International Food Policy Research Institute (IFPRI) (2010): Fertilizers and soil fertility potential in Ethiopia: Constraint and opportunities for enhancing the system, working paper, Washington.
Jarvan M Liina Edesi and Ando Adamson (2012): The content and quality of protein in winter wheat grains depending on sulphur fertilization. Soil and Plant Science, 62 (7): 627-636.
Landon JR (1991): Booker Tropical Soil Manual: A hand book for soil survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical, Essex, New York. 474p. OR John Wiley & Sons Inc., New York.
Lawrence JR Ketterings QM and Cherney JH (2008): Effect of nitrogen application on yield and quality of corn. Agronomy Journal, 100 (1): 73-79.
Legesse Amsalu (2004: Response of tef *[Eragrostis tef (Zucc.) Trotter]* to applied nitrogen and phosphorus in Sirinka, North Eastern Ethiopia. MSc Thesis, Alemaya University, Alemaya, Ethiopia.
Lemlem Hiwot (2012): Evaluating the effect of low seeding rate, planting method and blended fertilizer application on *Eragrostis tef* (Kuncho variety) yield, yield component and nutrient uptake by grain grown on Regosols and Vertisols. MSc thesis, Mekelle University, Mekelle, Ethiopia.
Marx J Hart and Stevens RG (1999): Soil Test Interpretation Guide. Oregon State University Extension Service, EC 1478.
Mohantty M Reddy SK Prober ME Dalal RC Rao SA and Menzies NW (2011): Modelling nitrogen mineralization from green manure and farmyard manure from a laboratory incubation study. Ecol.Model. 222, 719-726
Okubay Giday, Heluf Gibrekidan and Tareke Berhe (2014): Response of tef (Eragrostis tef) to different rates of slow release and conventional urea fertilizers in Vertisol of southern Tigray, Ethiopia. Advances in Plants and Agricultural Research, 1(5): 1-8.
Olsen R Cole S Watanabe and Dean L (1954): Estimation of available phosphorusinsoils by extraction with sodium bicarbonate. United States Department of Agriculture Circ. 939.
Ramswaroop Jat, Sita Ram Naga, Rajsingh Choudhary, Shyopal Jat and Irfan Mohammad (2017): Effect of Potassium and Sulphur Fertilization on Soil Fertility of Sesame (*Sesamum indicum* L.) *International Journal of Chemical Studies.* 5(2): 95-96.
Rattal L and Manjok Shukla (2004): Principles of soil physics. Marcel Dekker, Inc. New York • basel
Refissa Leta (2012): Effects of sowing methods and fertilizer types on yield and yield components of tef [*Eragrostis tef* (Zucc.) *Trotter*] at Guduru woreda, Western Oromia, Ethiopia. M.Sc. thesis, Haramaya University, Haramaya, Ethiopia.
Reinke RF Lewin LG and Williams RL (1994): Effect of sowing time and nitrogen on rice cultivars of differing growth duration in New South Wales. Yield and yield components; Australian Journal of Experimental Agriculture 34(7):933–938.
Seyfu Ketema (1993): Tef [*Eragrostis tef* (Zucc)*Trotter]*. Breeding, Genetics Resources, Agronomy, Utilization and Role in Ethiopian Agriculture. Ethiopian Institute of Geological Surveys, Ministry of Mines and Energy, Addis Ababa, Ethiopia.
Seyfu Ketema (1997): Tef [*Eragrostis tef* (Zucc) *Trotter*]. Promoting the conservation and use of underutilized and neglected crops. Institute of Plant Genetics and Crop Plant Research, Getersleben International Plant Genetic Resources, Rome, Italy

Shaun Casteel, Jim Camberato and Stephen Maloney (2012): Sulfur deficiency in Corn. Purdue University Department of Agronomy, Soil Fertility Update. Available at: http://www.kingcorn.org/news/timeless/SulfurDeficiency.pdf.

Statistical Analysis System (SAS) (2009): SAS/STAT User's Guide, Version 9.1.3. SAS institute Inc., Cary, NC

Tadesse Debele and Haile Deressa (2016): Integrated Management of Vertisols for Crop Production in Ethiopia: A Review. Journal of Biology, Agriculture and Healthcare. ISSN 2224-3208 (Paper) ISSN 2225-093X (Online), Vol.6, No.24.

Tekalign Tadese (1991): Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document. No. 13. International Livestock Research Center for Africa, Addis Ababa.

Temesgen Kassahun (2001): Effect of sowing date and nitrogen fertilization on yield and related traits of tef [*Eragrostis tef (Zucc.) Trotter*] on Vertisols of Kobo area, Northern Wollo. MSc Thesis, Alemaya University, Alemaya, Ethiopia.

Vavilov NI (1951): The origin, variation, immunity, and breeding of cultivated plants (translated from the Russian by K.Starr Chester). The Ronald Press Co.,New York.P.37-38

Wakene Tigre, Walelign Worku and Wassie Haile (2014): Effects of nitrogen and phosphorus fertilizer levels on growth and development of barley (Hordeum vulgare L.) at Bore Woreda, Southern Oromia, Ethiopia. American Journal of Life Sciences, 2(5): 260-266.

Wassie H and Tekalign M (2013): The Effect of Potassium on the Yields of Potato and Wheat grown on the Acidic Soils of Chencha and Hagere Selam in Southern Ethiopia. *International potash institute*, e-ifc No. 35.

Response of tef (*Eragrostis tef* /Zucc./Trotter) to NPS and NPSFeZn Blended Fertilizers on Vertisols in Raya Azebo Woreda, Northern Ethiopia

Hayelom Berhe

Mehoni Agricultural Research Center, Ethiopian Institute of Agricultural Research,
P.O. Box 47, Mekhoni, Tigray, Ethiopia
Correspondence: hayelomberhe345@gmail.com

Abstract

Field experiments were conducted to investigate the response of tef, variety *DZ-cr-37* (*Tseday*), grown on a Vertisol to the application of blended fertilizers'tef, during the 2016/17 and 2017/18 main cropping season in Raya Azebo Woreda, Southern Zone of Tigray, northern Ethiopia. The experiment consisted of 10 treatments. These were 8 different rates of two types of blended fertilizers (NPS and NPSFeZn), blanket recommended NP (41N + 20P kg ha^{-1}) and a control. The experiment was laid out in randomized complete block design (RCBD) with three replications. Highest plant height, effective tiller number, panicle length, grain yield and biomass yield were obtained from application of 100 kg ha^{-1} of NPSFeZn + 100 kg urea ha^{-1} followed by 100 kg ha^{-1} of NPSFeZn+ 50 kg urea ha^{-1}. This might be due to additional sulfur (S), iron (Fe) and zinc (Zn) nutrients in the blended fertilizer. However, economically highest grain (1962 kg ha^{-1}) and straw (3985 kg ha^{-1}) yields over years were recorded with the application of 100 kg ha^{-1} NPSFeZn blended fertilizer with 50 kg urea ha^{-1} or (41N + 38P_2O_5 + 6.5S + 0.3Fe + 2.2 Zn) kg ha^{-1}. Therefore, this blended rate with 50 kg urea ha^{-1} to increase productivity of tef in the study area.

Key words: Tef, blended fertilizers, Grain yield, Yield components, Vertisols

Introduction

Tef is a small-grained cereal that has been grown as food crop in East Africa for thousands of years (D'Andrea 2008). Tef adapts to diverse agro-ecological regions in Ethiopia (Refissa 2012). According to Seyfu (1997), the plant can be grown from sea level up to 2800 masl under various rainfall conditions, temperature and soil regimes. However, for better performance, it requires an altitude of 1800-2100 m.a.s.l., annual rainfall of 750-850 mm, and a temperature range of 10-27^{0}C. The grains of tef are used to bake "Injera" (Haftamu et al 2009), which is popular food of the Ethiopians. Tef's excellent nutritional value and high resilience in resisting diverse biotic and abiotic stresses make it an excellent food security crop. Tef grain, owing to its high mineral content, has been used in mixtures with soybean, chickpea and other grains in the baby food industry (Seyfu, 1997). In recent days, tef is among the cash crops and has been attracting an export market due to its nutritional value and is believed to be gluten free (Patricia and Lisette Van 2008). Tef straw, besides being the most appreciated feed for cattle, it is also used to reinforce mud and plaster the walls of house and local grain storage facility called *gotera*.

Tef straw is stored and used as a very important source of animal feed, especially during the dry season. Farmers feed tef straw preferentially to lactating cows and working oxen. Cattle prefer tef straw over other cereal straw and for this reason, its price is higher than that of other cereals.

Tef is one of the most important food cereal crops in Ethiopia, occupying about 24.02% (3,016,053.75 ha) of the cultivated land and accounting 17.57% of the grain production [Central Statistical Agency (CSA), 2017]. It is in this context that tef was selected as test crop for this study. However, the national average yield for tef was below (1 ton per hectare). Any technology that will improve tef yield will greatly benefit tef farmers and the country at large [Agricultural Transformation Agency (ATA), 2014]. Different factors contribute to the low yield of tef. The first major production constraint of tef in Ethiopia is poor soil fertility management (CSA 2013). The low national grain yield of tef compared to other cereals could be associated with the use of traditional and poor soil fertility management and lack of other appropriate management practices (Brhan 2012). The second main problem in the study area is lack of information on the agronomic and economic role of blended fertilizer. Blended fertilizers are a combination of macro and micro nutrients. The main advantages of blended fertilizers to the farmers are: nutrients are supplied in ratios to suit the needs of particular soils and crops; the cost per unit of plant nutrient is generally low; the cost of transportation and spreading is low because of the high analysis of bulk blends (Roy et al 2006).

The current productivity obtained from tef using the recommended blanket fertilizers is very low compared to the potential yield of the crop, in all parts of the country. Frequent use of diammonium phosphate (DAP) and urea without considering the other nutrients may have led to deficiencies of potassium (K) and other nutrients (Astatke et al 2004). Similarly Bereket et al (2011) reported improvement of tef yield from application of Zn fertilizer. Recent completed research and soil tests through the Ethiopian Soil Information System Project revealed that Ethiopian soils are deficient in various other nutrients that are not provided by DAP and urea (ATA 2013). Recently, it was reported that crops have been suffering from deficiencies of several nutrients throughout the country. According to the atlas of soil fertility made by Ethiopian Soil INformation System (EthioSIS), seven soil nutrients [nitrogen (N), phosphorus (P), K, S, Fe, Zn and boron (B)] are found to be deficient in the soils of Tigray region (ATA, 2014). Deficiency of the nutrients can be alleviated by application of blended fertilizers: the mechanical mixture of two or more granular fertilizer materials containing N, P, K and other essential plant nutrients such as S, Zn, and B, recently known to Ethiopia. Application of balanced fertilizers could be the basis to produce more crop output from existing land under cultivation and nutrient needs of crops according to their physiological requirements and expected yields (Ryan 2008).

Currently, fertilizers are being blended in Ethiopia, including Tigray region by farmers cooperatives based on specific soil nutrient needs to the areas. Application of micronutrients in the form of blended fertilizer has begun to be practiceed by farmers in Raya Azebo and Raya Alamata. However, the rate for the blended fertilizers had not been verifiedsofar. Nowadays tef is also becoming the most preferred crop both for consumption and for its market value. However, its production and productivity is still very low due to traditional agronomic practices and nutrient deficiencies. Thus, the present study was initiated with the objectives to investigate the effect of different rates of blended fertilizers (NPS and NPSFeZn) and to assess economic feasibility on yield and yield components of tef on Vertisols in Raya Azebo Woreda.

Materials and Methods

Description of the study area

The study was conducted in 2016/17 and 2017/18 consecutive years during the main cropping seasons at Fachagama site of Mekhoni agricultural research center, located in Southern zone of Tigray region, northern Ethiopia (Figure 1). The topography is gentle slope. The climatic condition of the Raya Azebo Woreda is semi- arid. The study area, Raya Azebo Woreda, is under hot to warm sub-moist lowlands agro-ecology (SM1-3a). The Woreda is located at $12^0$40'0"N latitude and $39^0$44'01" E longitude at an altitude of 1620 m.a.s.l. The area receives bimodal rainfall with low and erratic distribution. The main rainy season (Meher) starts from end of June to early September and the highest amount of rain in July and August, where as the short rain season (Belg) starts in February and ends in March. The mean annual rainfall ranged from 400 – 700 mm. The mean annual rain fall from 2008 – 2017 was 564.4 mm. Total annual rainfalls ranges from 421.2 mm in 2008 to 691 mm in 2010. This showed that there was high variability of the rainfall between different years and more of the annual rainfall falls in July and August.

The maximum temperature of the area during warmer season is around 33.3^0C on June while the minimum during cold season is 12.1^0C on January and December, but the average is 22.7^0C. The highest (33.3^0C) and lowest (26.3^0C) maximum temperatures were recorded on June and on December. In addition, the highest and lowest minimum temperature was recorded on June (19.44^{0}C) and on January (12.1^{0}C), respectively (National meteorology data of Mekelle branch 2017).

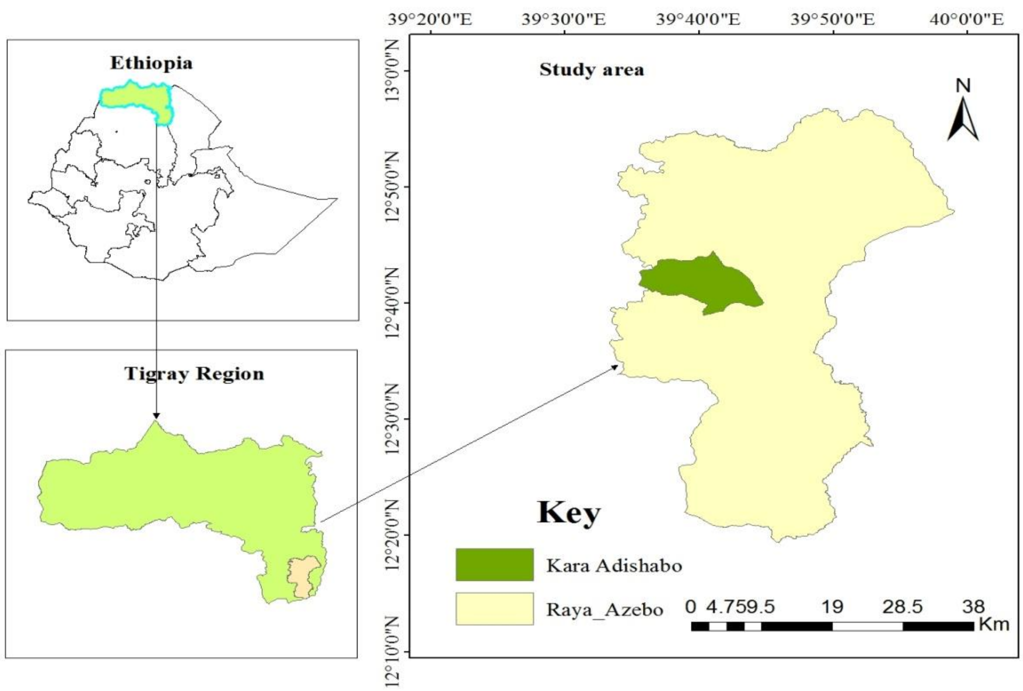

Figure 3. Location map of the study site at Raya Azebo, Southern Tigray, Ethiopia

Geographically the experimental site /Fachagama/ is located at latitude of 12°41’50” N and longitude of 39°42’08” E. with an altitude of 1571 m.a.s.l. (Haileslassie et al 2015). The site receives a mean annual rainfall of 539.7mm with an average minimum and maximum temperature of 15.6°C and 29.5°C, respectively (MeARC 2017).

The farming system of the area is mixed (crop and livestock). Sorghum, tef, maize are the major crops while wheat, barley and legumes like chickpea rotation are minor. The soils of Raya valley do not show extensive variation and are limited to four main soil types: Vertisols, Fluvisols, Luvisols and Cambisols (FAO 1990). The experimental site is Vertisol (black clay soils). The soil (Vertisols) textural class of the experimental site isclay with pH of 8.2.

Experimental materials, treatments and design

An improved tef variety known as *DZ-cr-37* (tseday), which is the most adapted and widely used by farmers, was sown by hand drilling. The experiment consisted of 10 treatments. These were 8 different rates of two types of blended fertilizers (Formula 1: NPS and Formula 2: NPSFeZn), blanket recommended NP (41N + 20 P kg ha^{-1}) and unfertilized (control). However, urea was also combined with each blended fertilizers at 50 kg and 100 kg ha^{-1} rates. The recommended NP was based on the recommendation of Ministry of Agriculture of Ethiopia while the formula 1 NPS (19 N - 38 P_2O_5 + 7S) and formula 2 NPSFeZn (17N-35P_2O_5 +8S +0.3Fe +2.2 Zn) were based on that of EthioSIS map (ATA 2014). The experiment was laid out in RCBD with three replications. The plot size was 4m by 3m with 20cm inter row spacing. The spacing between blocks and plots of the experiments was 2m and 1m, respectively. Thus, the experiment had detail treatments as shown in Table 1.

Table 1. Details of fertilizer treatments used in the experiment

Treatments	Nutrient (kg ha^{-1})					
	N	P_2O_5	S	Fe	Zn	Additional N
1. Control treatment (CT)	-	-	-	-	-	-
2. Recommended NP (RNP)	41	46	-	-	-	-
3. Formula 1:100 kg/ha NPS+50 kg Urea	19	38	7	-	-	23
4. Formula 1:100 kg/ha NPS+100 kg Urea	19	38	7	-	-	46
5. Formula 1:150 kg /ha NPS+ 50 kg Urea	28.5	57	10.5	-	-	23
6. Formula 1:150 kg/ha NPS+100 kg Urea	28.5	57	10.5	-	-	46
7. Formula 2:100 kg/ha NPSFeZn+50 kg Urea	17	35	8	0.3	2.2	23
8. Formula 2:100 kg /ha NPSFeZn+100 kg Urea	17	35	8	0.3	2.2	46
9. Formula 2:150 kg/ha NPSFeZn+50 kg Urea	25.5	52.5	12	0.45	3.3	23
10.Formula 2:150 kg/ha NPSFeZn+100 kg Urea	25.5	52.5	12	0.45	3.3	46

Recommended seed rate (5 kg ha^{-1}) for row planting (Berhe et al 2011) was used and sown in 2016/17 and 2017/18 during main seasons on Vertisols. For the row planting treatments, seeds were drilled at 20 cm spacing (Berhe et al 2011) between rows and placed in a depth of 0.6-1.3 cm (Evert et al 2008) under shallow soil cover. During planting, triple super phosphate (TSP) and blended fertilizers were applied in the soil as band application (5 cm) away from the seed by making a shallow furrow along the tef row and depositing the fertilizer on the bottom of the furrow not to contact with the seed and then covering with soil. Habtegebriel and Singh (2006) reported that N should be applied in split (at sowing and during tillering) for optimum nutrient use efficiency of tef for all the treatments except the control. Furthermore, during the different growth stages of the crop, all the necessary agronomic and other management practices were carried out according to the farmer practice.

Experimental procedures and field management

The experimental plot at first was ploughed by tractor while the second and third preparation were using local plow (maresha) pulled by oxen according to farmers' conventional practice. Accordingly, the field was plowed three times before sowing. The plot size was 4 m by 3 m (12 m^2) each containing 20 planting rows of 4 m length at spacing between rows of 20 cm. The plots within a block were separated by 1 m whereas the blocks were separated by 2 m wide open space area. The net plot size was 3m by 2m (6 m^2). Samples were harvested, leaving 1m on both sides of each plot, to avoid possible border effects. The TSP and blended fertilizers were applied during planting but urea fertilizer was applied in two equal splits, the first half at the time of sowing and the second half was side-dressed at the mid tillering stage of the crop. Urea fertilizer was incorporated 3-4 cm deep into the soil with 5 cm distance from the planting row at the time of sowing. Furthermore, during the different growth stages of the crop, all the necessary agronomic and other management practices were carried out which was based on farmers' practice.

Harvesting was done when the senescence of the leaves took place as well as the grains came out free from the glumes when pressed between the forefinger and thumb. The harvested produce was sun dried for 10 days. Then after the threshing and winnowing was done manually. Finally the grains were measured with sensitive balance.

Data collection and measurements

Soil sampling and analysis

Soil samples (0-30 cm depth) were collected from the experimental field by Auger sampler using X-shaped pattern from the whole experimental plots and composited into one sample before sowing the crop. From this mixture, a sample weighing 1.0 kg was taken. Air dried soil sample was ground with a pestle and mortar. Before analysis, the sample was sieved through a 2-mm sieve (8 meshe). The soil analysis was done for organic matter, soil pH, total N, available P, CEC, available S and Zn. Organic carbon (OC) was estimated by the wet digestion method (Walkley and Black 1934) after air dried soil grounded to pass a 0.2 mm sieve.

Total N was determined using the Kjeldhal method (Jackson 1958). The pH of the soil was measured in water to soil ratio of 1:2.5 using potentiometric-pH meters with glass electrode. Available P was determined with Olsen method (Olsen et al 1954). To determine the CEC, the soil sample first was leached using 1 M ammonium acetate, washed with ethanol and the adsorbed ammonium was replaced by sodium (Na). Then, the CEC was determined titrimetrically by distillation of ammonia that was displaced by Na (Sahlemedhin and Taye 2000). Available S was determined by monocalcium phosphate extraction method or turbidimetric estimation (Hoeft et al 1973) and available Zn was determined by DTPA (dietylenetriaminepentaacetatic acid) method (Lindsay and Norvell 1978).

Phenological and growth data

Days to 50% heading was determined by counting the number of days from sowing to the time when 50% of the plant panicles started to emerge through visual observation. Days to 90% maturity was determined as the number of days from sowing to the time when the plants reached maturity based on visual observation. Plant height was measured at physiological maturity from the ground level to the tip of panicle from randomly selected five culms each from two pre demarked 0.5 m row length in the net plot area. Thus this was based on the average of 10 culms per net plot area. The length of the panicle from the node where the first panicle branch emerged to the tip of the panicle was measured from randomly selected five culms each from two pre demarked 0.5 m row length in the net plot area. Thus this was based on the average of 10 observations.

Yield components and yield

Total number of tillers was determined by counting the total number of tillers from pre tagged ten plants from the net plot area. Number of effective tillers was determined by counting the tillers which had a panicle from the above pre tagged plants. Thousand kernel weights were determined by carefully counting 250 kernels and weighing them using a sensitive balance and was multiplied by four. Grain yield was measured by harvesting the crop from the net plot area. The grain moisture was adjusted to 11.5%. At maturity, the aboveground dry biomass was measured after drying the harvested produce from the net plot area till a constant weight. Straw yield was estimated by subtracting grain yield from aboveground dry biomass. Harvest index (HI) was calculated by dividing grain yield by the total aboveground dry biomass yield.

The degree of lodging was assessed just before the time of harvest by visual observation based on the scale of 1-5, where 1 (0-15^0) indicates no lodging, 2 (15-30^0) 25% lodging, 3 (30-45^0)50% lodging, 4 (45-60^0) 75% lodging and 5 (60-90^0) 100% lodging (Donald 2004). The scale was determined lodging by the angle of inclination of the main stem from the vertical line to the base of the stem by visual observation. Data recorded on lodging percentage was subjected to arc sine transformation described for percentage data by Gomez and Gomez (1984).

Data analysis

The crop data of both years separately and combined by years were subjected to the analysis of variance (ANOVA) using the Statistical Analysis System(SAS) (9.0) software computer package (SAS Institute, 2002) and significance difference among the treatment means was computed with Duncan's Multiple Range Test (DMRT) at 5% probability level (Gomez and Gomez 1984).

Partial budget analysis

Economic analysis was performed to investigate the economic feasibility of the treatments. Partial budget, dominance and marginal analyses were calculated based on the technique described by [International Maize and Wheat Improvement Center (CIMMYT), 1988]. The average grain yield was adjusted to 10% downwards to reflect the difference between the experimental yield and the yield farmers will expect from the same treatment. Two years (2016/17-2017/18) average open market price (13ETB kg^{-1}) for tef crop based on the information obtained from bureau of agriculture office of Raya Azebo (2016 and 2017) was used for analysis. The official prices of fertilizers according to bureau of agriculture office of Raya Azebo (2016 and 2017) of TSP (14.06 ETB kg^{-1}), Urea (10.66 ETB kg^{-1}), NPS (11.40 ETB kg^{-1}) and NPSZn (17.97 ETB kg^{-1}) were used. The price of ferrous sulphate (11.40 ETB kg^{-1}) was used based on the market price of Niway Chemicals PLC at Addis Ababa. Those all fertilizers were used for analysis. The costs of straw, transportation and daily labour were also taken from the study areas. A treatment was considered worth to farmers when it's minimum acceptable rate of return (MAR) is 100% (CIMMYT 1988), which is suggested to be realistic. This enables' to make farmer recommendations from marginal analysis.

It reveals the economic performance of the treatments based on grain yield of tef. Gross return (yield x price) and net return (gross return – total varying cost) were calculated to carry out marginal rate of return (MRR) analysis which is important for correct evaluation of alternative technologies. The varying fertilizer, transport and labor costs were estimated based on the existing transport cost and fertilizer purchase and daily labor payment. The yield (grain) harvested from the plots were converted into hectare basis and the market values of both components were calculated based on the existing market price. Costs that do not vary among all treatments are not included in the analysis.

In this study, MRR analysis was carried out on both dominated and un-dominated treatments in a stepwise manner, starting from control to the other treatments. CIMMYT (1988) and Asumadu et al (2004) provided the minimum rate of return that ranges between 40% and 100%, whereas Farquharson (2006) and Shah et al (2009) suggested minimum rate of return to be 100%, especially for poor farmers in developing countries or for technologies requiring substantial change to a farming system. Accordingly, in this study, 100% marginal rate of return was considered as a guarantee for the farmers to accept a new technology without doubt.

Results and Discussion

Soil Physico-chemical properties of the experimental site

Selected soil characteristics of the experimental soil are presented on Table 2. The soil texture class was dominated by clay. Soil texture influences water holding capacity, water intake rates, aeration, root penetration and soil fertility. The soil pH was strongly alkaline according to the rating of Tekalign (1991). The higher pH may hinder availability of nutrients such as P, Zn and Fe in the soil. The CEC of the soil was very high (>40 cmol (+) kg^{-1}) according to the rating of Landon (1991). This indicate the soil is very good agricultural soil. The OC content was low (<2%) (Landon 1991). Similarly total N was also low (Tekalign et al 1991). Available P content of the soil was high (>10 mg kg^{-1}) according to Olsen (1954). The experimental soil was found to be salt free (<4 dS m^{-1}). The analysis for other soil chemical properties indicated that the experimental soil had values of 0.35 meq L^{-1} SO_4^{-2} and 2.03 mg/100g soil of available S and available Zn, respectively.

Table 2. Soil chemical characteristics of the experimental field before sowing

$pH\text{-}H_2O$	EC (dS m^{-1})	Particle size distribution				OC (%)	CEC (cmol (+) kg^{-1}	TN (%)	P-Olsen (mg kg^{-1})	S (meq l^{-1} $SO4^{-2}$)	Zn (mg kg^{-1})
		Sand (%)	Clay (%)	Silt (%)	Texture class						
8.2	2.08	10.6	50.4	39	Clay	0.78	45.95	0.12	14.6	0.35	2.03

Effects on phenological and growth parameters

Number of days to 50% heading and days to 90% physiological maturity were significantly ($p<0.001$) affected by application of blended fertilizers (Table 3). The maximum days to heading and maturity were recorded at application of 150 kg ha^{-1} (NPSFeZn) with additional 100 kg urea ha^{-1} while the minimum was observed under the control. This result indicated that the fertilizer blended in different proportions of N, P, S, Fe and Zn and higher amount of Zn and urea might have contributed to the delayed number days to heading and maturity of tef. Shiferaw (2012) also reported application of fertilizer reduced days to flowering compared to unfertilized treatment in tef. In general, the days to heading and maturity of tef plants were hastened under no or lower N, Fe and Zn rates than under the higher rates

Analysis of variance showed that plant height was significantly affected by the rate of blended fertilizers (Table 3). The maximum difference between the plant heights obtained under different blended fertilizer treatments was about 6.3 cm. The shortest plant height was recorded from control. The result of this finding has agreed with Sate (2012) who reported that plant height of tef was significantly affected by application of P_2O_5 and N with blended fertilizer.Panicle length is one of the yield attributes of tef that contribute to grain yield. Crops with higher panicle length could have higher grain yield. Significantly highest panicle length was recorded at application of 100 kg^{-1} ha NPSFeZn plus100 kg urea ha^{-1}. The shortest panicle length was recorded at control. The finding of this result was similar to that of Haftom et al (2009) who reported that tef panicle length increased in response to increasing rate of N application.

Analysis of variance indicated that there was significantly difference ($p<0.05$) among treatments for total and number of effective tillers of plant (Table 3). Crops with higher number of effective tillers could have higher grain and biomass yields. Higher significant number of total and effective tillers $plant^{-1}$ were obtained from crop supplied with 100 kg^{-1} ha NPSFeZn plus 100 kg urea ha^{-1} and the minimum was observed from control treatment. The result indicated that blending of fertilizers with different macro and micro nutrients bring significant effect on those treatments having the higher dose of Fe, Zn with N in all the treatments.

Table 3. Effect of blended fertilizer rates on phenological and growth parameters of tef during 2016/17 and 2017/18 cropping season at Fachagama

Treatments	Days to 50% heading	Days to 90% maturity	Plant height (cm)	Panicle length (cm)	Number of total tillers plant^{-1}	Number of effective tillers plant^{-1}
1. Control treatment (CT)	46.17c	86.3f	72.7d	21.4e	5.9c	4.2e
2. Recommended NP (RNP)	47.3ab	88.0de	75.5bc	23.4d	7.2c	5.3cd
3. F1:100 kg/ha NPS+50 kg Urea	47.17ab	87.3e	74.0cd	23.0d	6.4c	4.5de
4. F1:100 kg/ha NPS+100 kg Urea	47.73abc	88.17d	74.17cd	24.4cd	6.5c	5.1cde
5. F1:150 kg /ha NPS+ 50 kg Urea	46.83bc	88.8cd	72.83d	23.8d	6.5c	5.0cde
6. F1:150 kg/ha NPS+100 kg Urea	47.5ab	88.8cd	74.17cd	25.4bc	7.13c	5.9c
7. F2:100 kg/ha NPSFeZn+50 kg Urea	47.1bc	88.5cd	75.18bc	25.4bc	10.2ab	8.7ab
8. F2:100 kg /ha NPSFeZn+100 kg Urea	47.83ab	90.0ab	79.02a	27.1a	10.9a	9.6a
9. F2:150 kg/ha NPSFeZn+50 kg Urea	47.5ab	89.3bc	76.42b	25.4bc	9.1b	7.8b
10.F2:150 kg/ha NPSFeZn+100 kg Urea	48.17a	90.5a	79.0a	26.02ab	9.7ab	7.9b
CV (%)	1.5961	0.7519	2.0556	4.6503	13.4286	12.136

Duncan's Multiple Range Test. Mean values followed the same letter(s) are not significantly different at LSD 5%; LSD (0.05) = least significant difference at 5% probability level; NS= Not significant; CV (%) = coefficient of variation

The reason was treatments containing Fe and Zn might have played a significant role in the formation of effective and total tillers. The finding of this research was in line to that of Brhan (2012) who reported that application of blended fertilizer brought significant difference in these parameters. However, there is disagreement with that of Esayas (2015) who reported no significant difference in total and productive tillers plant^{-1} among different blended fertilizers in wheat.

Effects on yields and lodging

There was significant ($p<0.01$) difference in grain yield due to application of blended fertilizer rates and urea (Table 4). The highest grain yield (2000.8 kg ha^{-1}) was recorded from application of 100 kg NPSFeZn ha^{-1} with additional 100 g urea ha^{-1} while the lowest yield (1265 kg ha^{-1}) was recorded from the control. The highest grain yield observed could be due to the combined effect of nutrients- N, P, S, Fe and Zn in blended fertilizer plus the additional N fertilizer which might have favored condition in growth and development of the crop. It was also revealed that despite significant difference in number of effective tillers plant^{-1} (Table 3) and 1000 seed weight (Table 4) among the treatments, the panicle length might have contributed more to the cumulative effect of these yield components towards enhanced yield. The result of the current research work is similar to result of Lemlem (2012) who reported that application of blended fertilizer, P and urea significantly increased the N, P, S, Fe and Zn, concentration of tef grains and increased grain yield in Vertisols. This research finding is also in line with the recent findings of Tareke et al (2008) who concluded that blended fertilizer application increased tef yield.

Table 4. Effect of blended fertilizer rates on grain yields, harvest index, lodging and thousand grain weights of tef during 2016/17 and 2017/18 cropping season at Fachagama

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Biomass yield (kg /ha)	Harvest index %	1000 seed Weight (g)	Lodging (%)
1. Control treatment (CT)	1265e	2956d	4221e	30.1c	0.195g	4.3f
2. Recommended NP (RNP)	1558c	3486c	5044d	30.9bc	0.254d	12.8bc
3. F1:100 kg/ha NPS+50 kg U	1402d	3302cd	4704d	29.8c	0.217f	8.5e
4. F1:100 kg/ha NPS+100 kg U	1520c	3408cd	4928d	30.9bc	0.223ef	9.7de
5. F1:150 kg /ha NPS+ 50 kg U	1503cd	3476c	4979d	30.2c	0.227ef	10d
6. F1:150 kg/ha NPS+100 kg U	1587c	3526bc	5113cd	31.1bc	0.236e	11.5c
7. F2:100 kg/ha NPSFeZn+50 kg U	1962a	3887ab	5849ab	32.8ab	0.281ab	12.8bc
8. F2:100 kg /ha NPSFeZn+100 kg U	2001a	3904ab	5905a	34.8a	0.287a	14.1ab
9. F2:150 kg/ha NPSFeZn+50 kg U	1812b	3690abc	5502bc	33.1ab	0.263cd	13.7b
10.F2:150 kg/ha NPSFeZn+100 kg U	1810b	4009a	5819ab	31.1bc	0.271bc	15.5a
CV (%)	5.73	6.67	6.7	6.35	4.25	10.82

Duncan's Multiple Range Test. Mean values followed the same letter (s) are not significantly different at LSD 5%; LSD (0.05) = least significant difference at 5% probability level; LSD (0.05) = least significant difference at 5% probability level; NS= Not significant; CV (%) = coefficient of variation U= Urea

Straw and aboveground dry biomass yields were significantly ($p<0.001$) influenced by the blended fertilizers application (Table 4). The highest straw and above ground dry biomass yields were recorded at the highest NPSFeZn with 100 kg urea though it was statistically at par with other treatments consisting NPSFeZn. This showed that fertilizer consists of the nutrients N, P, S, Fe and Zn contributed to enhance the aboveground dry biomass yield of tef than recommended NP fertilization and blend fertilizer with NPS. This research finding is similar to that of Shiferaw (2012) who reported that above ground dry biomass yield was significantly affected by application of blended fertilizer and urea. Similar result was also reported by Bereket et al. (2011) who found significant increment in straw yield of tef with the application of 8.0 kg Zn ha^{-1}. Fageria et al (2011) also indicated that application of S enhanced the photosynthetic assimilation of N in crop plant.

Thousand grain weight of tef significantly ($p<0.001$) influenced by the blended fertilizer treatments (Table 4). There was variation from 0.195 to 0.287g per thousand grains among the treatments. The highest grain yield of thousand grain weight was observed at 100 NPSFeZn with 100 kg urea per hectare.

Harvest index was significantly ($p<0.001$) affected by the blended fertilizer treatments (Table 4). Highest harvest index (34.8%) was recorded from 100 NPSFeZn with 100 kg urea per hectare application. The lowest mean values of HI were recorded from control and NPS blended fertilizer. The low HI could be associated with the absence and or low amount and number of nutrients in the soil available for the crop. The absence of nutrient retards growth and finally leads to fail to produce well matured grains before the rainfall ceases. The finding of this result similar to that of Lemlem et al (2015) who reported that highest index showed increment in yield.

Lodging index was significantly affected by the rate of blended fertilizer (Table 4). Lodging can be affected by wind and heavy rain. Row planted tef better support the weight of the filled head of grain than broadcast planted. Lodging percentage was significantly higher on the plots treated with high rates of fertilizers. However, the lower lodging percentage was recorded from the control plots. Significantly highest lodging percentages (15.5%) and (14.1%) were form 150 or 100 kg NPSFeZn plus 100 kg urea per hectare while the lowest lodging percentage (4.3%) was recorded from unfertilized plot. Blended fertilizer increased lodging percentage by about 27.7% compared to control could be due to the strengthening the skeleton parts of tef plants. The finding of this research result Fageria (2009) who reported that lack of variation among treatment in response to application of blended fertilizers might be from the contribution of macro and micro nutrient like S, Fe and Zn on the strong morphological stand of tef which reduce the percentage of lodging. Similar findings were also reported by Berhe et al (2011).

Partial budget analysis

The most important step in performing partial budget analysis is the proper identification of data on the costs and benefits associated with the alternative technologies. It is known that farmers apply fertilizer so as to get profit. Achieving the goal of yield increment depends not only on the kind and amount of fertilizer but also on the cost of the fertilizer and price of the yields (Black 1992). Now days the demand and market price of tef grain and straw is high as compare to the previous time; that‘s why growers need to use fertilizer and increase both grain and straw as a result their income increases.

Table 5. Partial budget analysis of fertilizer use in crop production for variable costs, gross benefit and net benefit based on CIMMYT (1988) under different treatments

Trt	Straw Yield (kg ha^{-1})	Adj. Straw Yield (kg ha^{-1})	Grain Yield (kg ha^{-1})	Adjusted Yield (kg ha^{-1})	TCTV (ETB ha^{-1})	GB (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)
T1	2956	2660.4	1265	1138.5	0	16130.7	16130.7	
T3	3302	2971.8	1402	1261.8	1695.5	17889.3	16193.8	3.7
T2	3486	3137.4	1558	1402.2	1975.5	19797.3	17821.8	581.4
T5	3408	3067.2	1520	1368	2236	19317.6	17081.6	D
T4	3476	3128.4	1503	1352.7	2273	19149.3	16876.3	D
T7	3887	3498.3	1962	1765.8	2366.66	24704.55	22337.89	5831.3
T6	3526	3173.4	1587	1428.3	2813.5	20154.6	17341.1	D
T8	3904	3513.6	2001	1800.9	2907.16	25168.5	22261.34	5253.3

T9	3690	3321	1812	1630.8	3279.74	22860.9	19581.16	D
T10	4009	3608	1810	1629	3820.24	25334	21513.76	357.56

DAP=14.2 ETB/kg^{-1}, TPS=14.06 ETB /kg^{-1}, Urea=10.66, NPS= 11.4 ETB /kg^{-1}, NPSZn=17.97 ETB /kg^{-1}, Fe=47.2 ETB /kg^{-1}, Labor cost=0.15 ETB /kg^{-1}, Transportation= 0.05 ETB /kg^{-1}, Tef= 13 ETB / kg^{-1}, Straw=0.05 ETB /kg^{-1}, Trt= Treatment, D= Dominance

Table 6. Data arrangement in cost increasing order and by using dominance and un-dominance

Treatments	Adjusted Yield cost (kg ha^{-1})		TCTV (ETB ha^{-1})	Gross Benefit (ETB ha^{-1})	Net Benefit (ETB ha^{-1})	MRR(%)
	Straw	Grain				
T1	2660.4	1138.5	0	16130.7	16130.7	
T3	2971.8	1261.8	1695.5	17889.3	16193.8	3.7
T2	3137.4	1402.2	1975.5	19797.3	17821.8	581.4
T7	3498.3	1765.8	2366.7	24704.6	22337.9	5831.3
T8	3513.6	1800.9	2907.2	25168.5	22261.3	5253.3
T10	3608	1629	3820.2	25334	21513.8	357.6

Economic analysis was performed after checking for the presence of significance difference of the mean grain yields of two years among the effect of the treatments. Partial budget, dominance and marginal analyses were performed (CIMMYT, 1988). The average yield was adjusted downwards by 10%, taking in to consideration that farmers could obtain 10% less yield than the experimental field. The price of TSP was computed from the price of 100kg of DAP based on the assumption that the nutrient content of DAP as 18% N and 46% P_2O_5 and that of TSP only 46% P_2O_5. Field price of tef of 2016/17-2017/18 was estimated to be 13 birr kg^{-1} from the markets of the study area. Accordingly, the prices of fertilizer types were collected. Transport cost of fertilizer and seed were 0.05 birr km^{-1} and costs of application 0.15 birr kg^{-1} were also included. The minimum acceptable rate of return (MARR) was set at 100% based on the suggestion by CIMMYT (1988).

Partial budget analysis showed that the higher return responses were obtained from application of 100 kg NPSFeZn plus 50 kg urea per hectare followed by 100 kg NPSFeZn plus 100 kg urea per hectare application (Table 6 and Table 7).

The analysis of variance showed that both grain and straw yield were highly significantly ($P < 0.05$) affected by the main effect of different rates of blended fertilizers and N (Table 4). According to the partial budget analysis, 100 kg NPSFeZn plus 50 kg urea per hectare provided the highest benefit (22358 ETB). The recorded benefit was 38.5% over the control treatment. Besides, application of recommended NP fertilizer showed 25.3% lower benefit 100 kg NPSFeZn plus 50 kg urea per hectare. The analysis of the Marginal Rate of Return (MRR) indicated all the application of blended fertilizers had higher than 100% which indicate tef production is profitable with the alternatives of T7, T8, T10 and T2. However application of 100 kg NPSFeZn plus 50 kg urea per hectare would be recommended both from the statistical and economic point of view.

Conclusion and Recommendation

In general, all the yield and yield components of tef (biomass yield, grain yield, harvest index, straw yield), thousand seed weight and lodging index were significantly influenced by the blended type and additional N (urea) fertilizers grown on Vertisols. It was possible to conclude that 100 kg NPSFeZn plus 50 kg urea per hectare and 100 kg NPSFeZn plus 100 kg urea per hectare showed significantly high grain yield, plant height, panicle length per plant, number of tillers per plant and thousand seed weight, straw yield than the other treatments. According to the partial budget analysis, 100 kg NPSFeZn plus 50 kg urea per hectare provided the highest benefit (22358 ETB). However application of 100 kg NPSFeZn plus 50 kg urea per hectare would be recommended both from the statistical and economic point of view on Vertisols of Raya Azebo. Application of blended fertilizers should be formulated based on soil test for a specific field not based on blanket recommendation. Therefore, on farm demonstration need to be conducted around the study area through involvement of as many farmers as possible and agricultural experts for further validation and verification of the study. Integrated Plant Nutrient System (IPNS) is important to improve sustainability and maintenance of soil productivity. Integrating chemical fertilizers with organic soil amendments would also sustain the soil and improve response of chemical fertilizers. Further research should focus on Integrated Plant Nutrient System (IPNS).

Acknowledgements

The author would like to acknowledge Ethiopian Institute of Agricultural Research (EIAR) for the financial and material support. Appreciation also goes to Mekhoni Agricultural Research Center and staff for their supporting the study. Sincere appreciation and thanks also go to Bereket Haileselassie (PhD), Senior Researcher at TARI, for his critical support in guiding and editing the manuscript.

References

Agricultural Transformation Agency (ATA) (2013): Transforming the use of fertilizer in Ethiopia: Launching the national fertilizer blending program. Addis Ababa, Ethiopia.

Agricultural Transformation Agency (ATA). (2014): “Soil Fertility Status and Fertilizer Recommendation Atlas for Tigray Regional State, Ethiopia,” Addis Ababa, .Ethiopia

Astatke A Mamo T Peden D and Diedhiou M (2004): Participatory on-farm conservation tillage trails in the Ethiopian highland Vertisols: the impact of potassium application on crop yields. *Experimental Agriculture*, (40):369–379.

Asumadu H Sallah PYK Boa-Amponsen PB Allou J Manu-Adunung and Osei-Bounsu (2004): On-farm evaluation and promotion of quality protein maize hybrids in Ghana. In: African crop science proceedings, Vol 4. Africa crop science society, pp. 358-364.

Bereket H Stomph T and Hoffland E (2011): Tef (*Eragrostis tef*) production constraints on Vertisol in Ethiopia: farmers' perceptions and evaluation of low soil zinc as yield-limiting factor. *Soil Science and Plant Nutrition*, (57): 587-596.

Berhe T Gebretsadik Z Edwards S and Araya H (2011): Boosting Tef Productivity Using Improved Agronomic Practices and Appropriate Fertilizer. In: *Achievements and Prospects of Tef Improvement. Proceedings of the Second International Workshop, November 7–9, 20*

Black CA (1992): Soil fertility evaluation and control. Lewis Publishers, USA.

Brhan Abayu (2012): Agronomic and Economic Effects of Blended Fertilizers under Planting Method on Yield And Yield Components of Tef: M.Sc Thesis, Mekelle University, Mekelle, Ethiopia.

Central Statistical Agency (CSA). (2013): Agricultural Sample Survey Report on area and production of major crops. Addis Ababa, Ethiopia.

Central Statistical Agency (CSA). (2017): Agricultural Sample Survey Report on area and production of major crops. Addis Ababa, Ethiopia.

CIMMYT (International Center for Maize and Wheat Research) (1988): From agronomic data to farmer recommendations: an economics training manual (completely revised edition). CIMMYT, Mexico, DF, pp 9-38.

D’Andrea AC (2008): Tef (*Eragrostis tef*) in ancient agricultural systems of Highland Ethiopia. *Economic Botany*, (62):547–566.

Donald LS (2004): Understanding and reducing lodging in cereals. *Advances in Agronomy, 84*: 217–271.

Esayas Lemma (2015): Effect of blended fertilizers on yield and yield traits of durum wheat (T*riticum turgidum l. var. durum*) varieties in Ada Woreda, Central Ethiopia. MSc. Thesis, Haramaya University, Haramaya, Ethiopia.

Evert S Staggenbong S and Olson B (2008): Soil temperature and planting depth effects on tef emergence. *Journal of Crop Science*, (195):232-236.

Fageria NK Baligar UC and Jones CA (2011): Mineral nutrition field crop; 3rd ed, Taylor and Francis press, Boca Raton.

Fageria NK (2009): The use of nutrients in crop plants: Taylor and Francis press Boca Raton, London and New York.

FAO (1990): Guidelines for Soil Description, 3rd Edition, Rome.

Farquharson R (2006): Production response and input demand in decision making: nitrogen fertilizer and wheat growers. Australasian Agribusiness Review - Vol.14 – 2006 Paper #5.

Gomez KA and Gomez AA (1984): Statistical Procedures for Agricultural Research.2nd ed. John Wiley and Sons, New York, USA.

Habtegebrial K and Singh BR (2006): Effects of timing of nitrogen and sulphur fertilizers on yield, nitrogen, and sulphur contents of tef (Eragrostis tef (Zucc.) Trotter). *Nutrient Cycling in Agroecosystem*, (75):213–222.

Haftamu Gebretsadik, Mitiku Haile and Charles FY (2009): Tillage Frequency, Soil Compaction and N Fertilizer Rate Effects on Yield of Tef (Eragrostis Tef (Zucc) Trotter) in Central Zone of Tigray, Northern Ethiopia *Momona Eth. J. Sci*, (1): 82–92

Haileslassie G Haile A Wakuma B and Kedir J (2015): Performance evaluation of hot pepper (*Capsicum annum* L.) varieties for productivity under irrigation at Raya Valley, Northern, Ethiopia. *Basic Research Journal of Agricultural Science and Review*, (4): 211-216.

Jackson ML (1958): Soil chemical analysis: prentice-Hall. Inc. Sixth printing Department of Soil Science, University of Wisconsin, Madison.

Landon JR (1991): Booker Tropical Soil Manual: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics. John Wiley & Sons Inc., New York.

Lemlem Hiwot (2012): Evaluating the effect of low seeding rate, planting method and blended fertilizer application on *Eragrostis tef* (Kuncho variety) yield, yield component and nutrient uptake by grain grown on Regosols and Vertisols. MSc thesis, Mekelle University, Mekelle, Ethiopia.

Lemlem H Shimbahri M and Muruts H (2015): Effect of Blended Fertilizer Application on (Eragrostis tef /Zucc./Trotter) Yield, Yield Component and Nutrient Uptake by Grain Grown on Regosols and Vertisols, North Ethiopia. *Journal of Natural Sciences Research*, (5).

Lindsay WL and Norvell WA (1978): Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Sci. Soc. Am. J.* 42: 421–428

Mehoni Agriculture and Rural Development (MARD) (2016): Fertilizer inputs in Mehoni. Tigray, Ethiopia

Minten B Tamru S Engida E and Kuma T (2013): Ethiopia's Value Chains on the Move: The Case of Tef. *ESSP II Working Paper 52*. International Food Policy Research Institute (IFPRI). Addis Ababa, Ethiopia.

National Meteorology (2017): Data on meteorology. Mekelle Branch, Mekelle Ethiopia

Olsen SR Cole CV Watanbe FS and Dean LA (1954) Estimation of available phosphorus in soils by extraction with sodium bicarbonate, 1-19. US. Gov. Print office, Washington DC, USA.

Patricia Arguedas G and Lisette Van E. (2008): TEF: "Survey on the nutritional and health aspects of tef (*Eragrostis tef*)". *Memorias Red-Alfa Lagrotech Comunidad Europea Cartagena, 319382.*

Refissa L (2012): Effects of sowing methods and fertilizer types on yield and yield components of Tef [*Eragrostis tef (zucc.) trotter*] at Guduru Woreda, Western Oromia, Ethiopia.

Roy RN Finck A Blair GJ and Tandon HLS (2006): Plant nutrition for food security: A guide for integrated nutrient management. FAO fertilizer and plant nutrition bulletin.FAO of the United Nations, Rome.

Ryan J (2008): A Perspective on balanced fertilization in the Mediterranean Region. *Turkey journal of Agriculture,* (32): 79-89.

Sahlemedhin S and Taye B (2000): Procedures for soil and plant analysis. National Soil Research center Technical Paper, 74.NFIA, Addis Ababa, Ethiopia.

SAS (2002): Statistical Analysis System (SAS). Institute Inc., SAS Campus Drive, Gary, NC, USA.

Sate Sahle (2012): Effects of inorganic fertilizer types and sowing methods of different seed rates on yield and yield components of tef in Boreda Woreda, southern Ethiopia. MSc. Thesis; Haramaya University, Haramaya, Ethiopia.

Seyfu Ketema (1993). Tef [*Eragrostis tef* (Zucc) Trotter]. Breeding, Genetics Resources, Agronomy, Utilization and Role in Ethiopian Agriculture. Ethiopian Institute of Geological Surveys, Ministry of Mines and Energy, Addis Ababa, Ethiopia.

Seyfu Ketema (1997): Tef [*Eragrostis tef* (Zucc) Trotter]. Promoting the conservation and use of underutilized and neglected crops. Institute of Plant Genetics and Crop Plant Research, Getersleben International Plant Genetic Resources, Rome, Italy.

Shah H Sharif M Majid A Hayat U and Munawar A (2009): From experimental data to farmer recommendation: An economic analysis of on-farm trial of UMMB feed for milking animals in rain-fed Pothwar, Pakistan. Livestock Research for Rural Development. http://www.lrrd.org. [Accessed April 4, 2012].

Shiferaw Tolosa (2012): Effects of inorganic fertilizer types and sowing methods of variable seed rates on yield and yield components of tef [Eragrostis tef (Zucc.) Trotter] in Ada"a Woreda, Central Ethiopia. M.Sc. Thesis, Haramaya University, Haramaya, Ethiopia.

Tareke B. (2008): Increasing Productivity of Tef, *Eragrostistef* (Zucc.) Trotter: New Approaches with Dramatic results (Unpublished Report), Addis Ababa, Ethiopia.

Tareke Berhe and Nigusse Zena. (2008): Results in a trial of system of tef intensification (STI) at Debrezeit, Ethiopia.

Tekalign Tadese. (1991): Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa, Ethiopia.

Teklu Y and Tefera H. (2005). Genetic Improvement in Grain Yield Potential and Associated Agronomic Traits of Tef (Eragrostis Tef). *Euphytica* 141.

Walkley A and Black CA (1934):.An examination of different methods for determining soil organic matter and the proposed modification by the chromic acid titration method. *Soil Sciences,* (37): 29-38.

Agronomic and Economic Evaluations of Compound Fertilizer Applications along with Different Tef [*Eragrostis Tef* (Zucc.) Trotter] Seed Sowing Practices

Teklay Tesfay[1*] and Girmay Gebresamuel[2]

[1]Aksum University, College of Agriculture, Department of plant sciences
[2]Mekelle University, Department of Land Resource Management and Environmental Protection, Tigray, Ethiopia.

*Correspondence: teklaytesfay62@yahoo.com; teklaytesfay2007@gmail.com

Abstract

Tef is the most preferred crop by Ethiopians for consumption and for its market value. However, its production and productivity is still very low due to traditional agronomic practices, nutrient deficiencies and susceptibility of the crop to lodging.Thus, this research work was conducted to examine the agronomic and economic performance of alternative ways of compound fertilizer applications under different sowing methods and seed rates. The experiment was conducted in North Ethiopia; on two soil types of Tahtay-Koraro Woreda during the 2011 main crop season. An improved tef variety ‘Quncho’ (Dz-Cr-387) was used as a test crop and 5 treatments evaluated using Randomized Complete Block Drsign (RCBD) with 3 replications. The treatments were: (1) band application of complete fertilizer underrow sowingtef at 5 kg ha^{-1} seed rate; (2) broadcast seed at 25 kg ha^{-1} seed ratewith complete fertilizer; (3) band application of diammonium phosphate (DAP) and urea underrow sowingtef at 5 kg ha^{-1} seed rate; (4) broadcast seed at 25 kg ha^{-1} seed rate with DAP and urea; (5) broadcasting tef at 25 kg ha^{-1} seed rate with no fertilizer application (control). Band application of complete fertilizer under row sowingtef at 5 kg ha^{-1} seed rate significantly improved grain yield by 320% on Vertisols and by 396% on Cambisols. However, result of the marginal rate of return (MRR) analysis revealed that band application of DAP and urea under row sowing of tef at 5 kg ha^{-1} seed rate gave the most economically profitable values of grain and straw.

Key words: Band application; Complete fertilizer; DAP and urea; sowing method; MRR

Introduction

Tef is a versatile cereal crop with respect to adaptation for the diverse agro-climatic and soil conditions (Deckers et al 2001; Tefera and Ketema 2001; Tefera and Belay 2006; Plaza et al 2009 and Chanyalew 2010). For this reason, it is cultivated annually on about 2.8 million hectares of land covering more than 28% of the total area annually under cereals in Ethiopia; but its estimated grain yield productivity is very low accounting only about 1.15 Mg ha^{-1} (CSA 2011).

Deficiency of N and P nutrients is the major tef yield limiting factor in Ethiopia (Tekalign et al 2001). However, the continuous management of Ethiopian soils by applications of only DAP and urea [nitrogen

(N) and phosphorus (P)] containing fertilizers for a long period of time has led to severe nutrient mining of the agricultural soils particularly when the entire crop biomass (grain and stover) are removed from the land. Recent findings showed that other nutrients such as potassium (K) (Haileselassie 2006); S (Habtegebrial and Singh 2006) and Zn (Bereket et al 2011) are also becoming tef yield limiting nutrients in different areas. Hence, the continuous use of DAP and urea should be supplemented with the application of additional compound fertilizers containing the above macro and micro nutrients. Thus, since deficiency of even only one nutrient can reduce crop yield; application of fertilizers containing K, sulfur (S), zinc (Zn) and other essential nutrients should be considered to improve tef productivity.Fertilizer or blend of fertilizers containing all the three primary nutrients (N-P-K) is termed as ‘complete’ fertilizer (McCauley et al 2009).

Yenesew et al (2011) confirmed that lack of improved tef variety, appropriate sowing method and seeding rate and low quality of soil limits crop yield. Besides, vulnerability of tef crop to lodging was also reported by various researchers as the major yield limiting factor. Broadcast sowing method of tef with high seed rate ($\geq$25kg ha^{-1}) is responsible for extremely high and uneven population distribution density and to the high competition for sunlight, moisture, and nutrients. Additionally, the placement of the seed on the soil instead of in the soil leads to extremely poor crown root development, lower tillering capacity and susceptibility to lodging and then lower yield.

Girmay et al (2009) described even though technically acceptable, many new technologies failed to function for a long period because of their high costs. Thus, evaluation of new technology in terms of its impact on the productivity, profitability, and acceptability is essential before giving any recommendations. Therefore, the objectives of this study were to (1) investigate the effect of complete fertilizer against DAP and urea application under different sowing methods and seed rates of tef, (2) determine the economic profitability of the compound fertilizers under different sowing methods and seeding rates.

Materials and Methods

Description of the study area

The experiment was conducted in the North Western Zone of Tigray Regional State, North Ethiopia; ontwo different soil types of Tahtay-Koraro Woreda during the 2011 main crop season. The experimental soils namely Cambisols and Vertisols (FAO/UNESCO 1977) are located at about 5 km to

East and 10 km to West of Shire town, respectively. They are situated at $13^0 88'36''$ to $14^0\ 08'\ 57''$N latitude and $38^0 04'30''$ to $38^0\ 17'\ 02''$ E longitudes at an altitude of 1902 m and 1917 m, respectively (Figure 1).

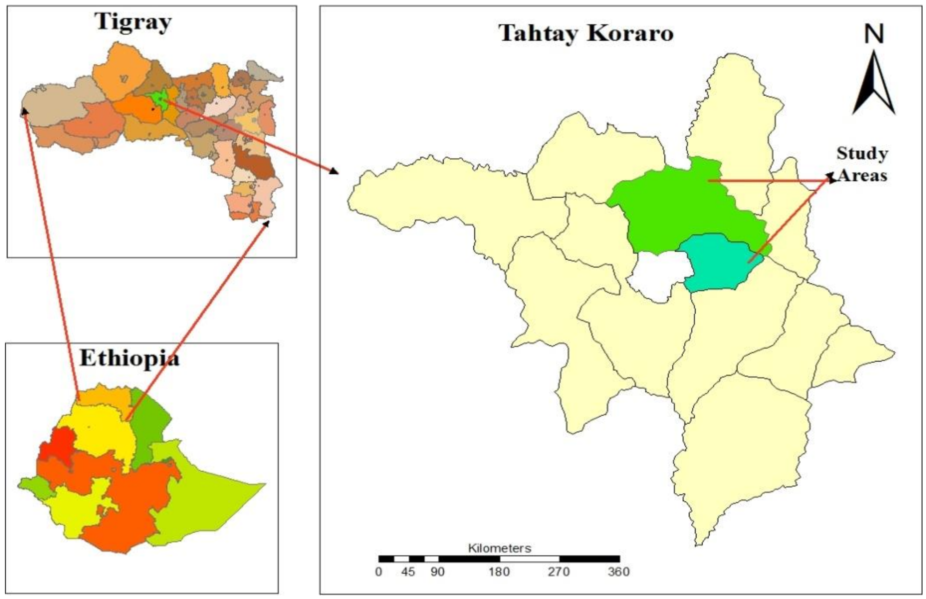

Figure 1. Location map of the study sites at Tahtay Koraro, Tigray, Ethiopia

The surfaces of the experimental soils (0 - 15cm) have high silt proportion (44%), but they differ in relative proportion of sand (16% on Vertisols and 30% on the Cambisols) and silt (40% on Vetisols and 26% on Cambisols). The Vertisols 6.7 pH, 0.117 dS/m electical conductivity (EC), 4.4% calcium carbonate ($CaCO_3$), 1.35% soil organic matter (SOM), 0.086% total N, 5.96 ppm available P, 0.83% available Zn, 26% available S (SO_4-S), and 1.08 cmol (+)/kg exchangeable K. On the other hand, the Cambisols contain 6.9 pH, 0.075 dS/m EC, 4.2% $CaCO_3$, 1.19% SOM, 0.069% total N, 4.84 ppm available P, 0.64% available Zn, 3% available S (SO_4-S), and 0.34 cmol (+)/kg exchangeable K.

Meteorological data were taken from one station (Shire station), assuming both experimental sites and the meteorological station are found under similar rainfall and temperature regimes. The main rainy season of study areas extend from June to September. The long term mean annual rainfall of the study areas for the past 15 years (1997-2011) was 1031.3 mm with minimum of 758.1 mm in 2002 and maximum of 1440 mm in 1999. Annual rainfall amount of the cropping season (2011) was 905.5 mm. Rainfall distribution of the study areas are characterized by unimodal pattern where more than 90% concentrate in the period between July and August. The average temperature of these study areas for the past 15 years revealed 20.92 ^{O}C with a mean maximum temperature record (30.97 ^{O}C) in April and the mean minimum (11.4 ^{O}C) in January. According to the climatic zone classifications of Ethiopia (Alemneh 2003), which was based on altitude, rainfall, average annual temperature and length of growing season,-the study areas belong to cool sub-humid agro-climatic zone.

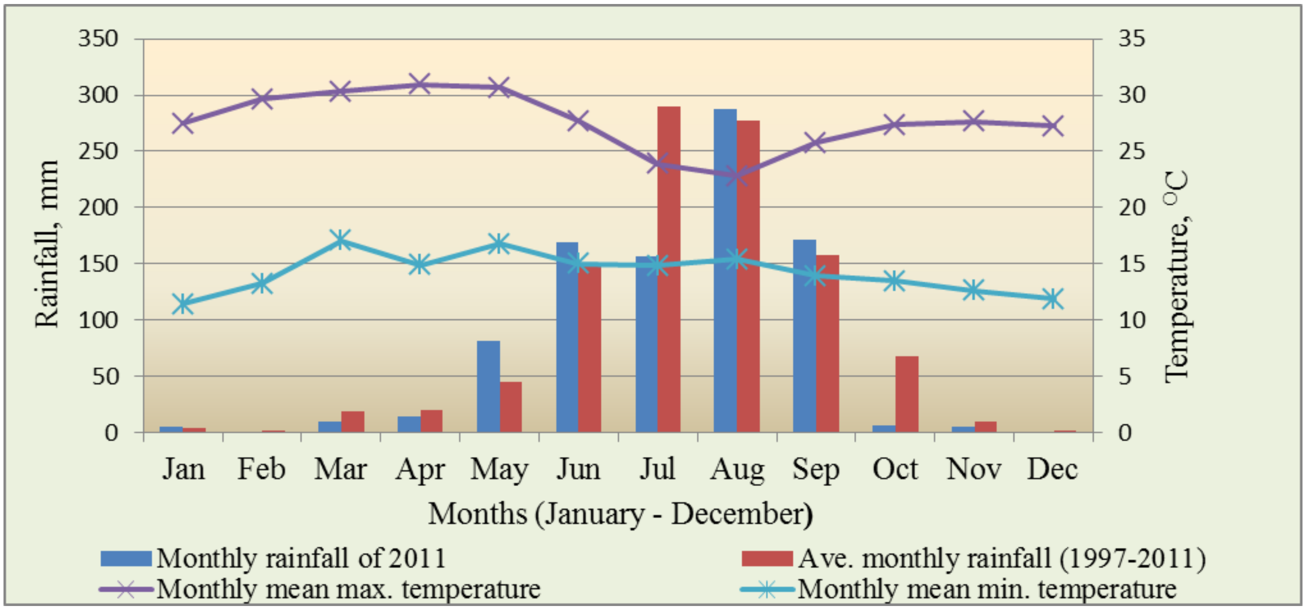

Figure 2. Monthly rainfall for 2011, monthly mean rainfall for the period 1997-2011, Monthly mean maximum and monthly mean minimum temperature for the period 1997-2011.

Experimental design and treatments

Improved tef variety 'Quncho' (Dz-Cr-387) was used as a test crop and five treatments in each site were laid out in randomized complete block design (RCBD) with three replications. Total area of one experimental site was 18 m by 23 m and the size of each plot was 4 m by 5 m with one meter free space between blocks and plots. Each treatment was assigned randomly to each experimental unit within each block and the treatments were:band application of complete fertilizer under row sowing tef at 5 kg ha^{-1} seed rate (T1); seed broadcast at 25 kg ha^{-1} seed rate with complete fertilizer (T2) band application of DAP and urea under row sowing tef at 5 kg ha^{-1} seed rate (T3); seed broadcast at 25 kg ha^{-1} seed rate with DAP and urea (T4); and seed broadcasting at 25 kg ha^{-1} with no fertilizer (Control).

One hundred kilogram Yara Milla Cereal constitutes 23N-10P-5K-3S-2Mg-0.3%Zn. Thus, 278 kg YMC (Yara Milla Cereal) combined with 39.5kg TSP gives 64 kg N and 46 kg of P (as P_2O_5) that can be obtained from 100kg DAP and 100 kg urea. Generally, the recommended amount of N (64 kg/ha) and P

(46 kg ha^{-1}as P_2O_5) were applied for all the treatments irrespective of the fertilizer type used, except the control.

Low seed rates (5 kg ha^{-1}) for row sowing and recommended seed rate (25 kg ha^{-1}) for the broadcast were used and were sown 19th July on the Vertisols and 20th July on Cambisols. For the row sowing treatments, seeds were drilled at 20cm spacing between rows and placed under shallow soil cover. During planting, 100 kg ha^{-1}DAP (46% P as $P_2O_5$and 18%N) and 39.5 kg ha^{-1}TSP (46% P as P_2O_5) were applied. However, YMC and urea were applied in splits and the 178 kg ha^{-1}YMC was applied at sowing and the remaining 100 kg ha^{-1}at tillering. In the same way, 50kg urea was applied at sowing and the other 50kg during tillering. Generally, 23 kg ha^{-1}N was applied during tillering for all the treatments except the control.

Prior to germination, in row plated plots, fertilizers were applied in the soil as band application 5 cm away from the seed planting) by making a shallow furrow along the tef row and depositing the fertilizer on the bottom of the furrow to prevent contact with the seed and then covering with soil. For the broadcast treatments (farmers practice), the fertilizer was broadcasted. At tillering stage, fertilizers were side dressed for the row planted tef and top dressed for the broadcasted tef. Weeding was carried out manually by hand three times during the growing season.

Agronomic data collection

Average reading of twenty randomly selected plants from each plot was used for measuring the agronomic data on plant height, panicle length, panicle seed weight and tillering in number. Lodging percentage was determined from the entire plot (4 m x 5 m). However, grain yield, straw yield, and harvest index (the ratio of the total grain yield to the total biomass yield harvested on dry weight basis) were recorded from net plot size of 3 m by 4 m to avoid border effect.

Soil Sample preparation and analysis

Prior to sowing 30 subsamples were collected from a depth of 0-15cm using auger and these soil samples were dried, composited, sieved through 2mm sieve to have 1kg composite sample for each study site. The collected soil samples were then analyzed for selected physico-chemical properties mainlyparticle size distribution, pH, electrical conductivity (EC), total N, available P, available S, available Zn, calcium carbonate ($CaCO_3$) and soil organic matter content at National Soil testing Center, Addis Ababa.

Texture (Particle size distribution) was determined by the hydrometer method (Bouyoucos 1962); Soil pH in a suspension of 1:2.5 soil water ratio by using pH meter (Peach 1965); EC of the soil extract was determined using EC meter (Sahlemedin and Taye 2000). Organic matter content of the soil was estimated from the organic carbon (OC) content determined using Walkley and Black (1934) method. To obtain percent of soil organic matter, percent of OC was multiplied by 1.724 since the organic matter is conventionally assumed to contain 58% carbon (58/100 = 1.724).

Total N determination was done by macro Kjeldahl method (Khee 2001). Olsen method was used to determine available P content of the soil (Olsen and Sommers 1982), available S using turbidimetric method (Kowalenko 1985), and available Zn was determined according to Lindsay and Norvell (1978) method using diethylene triamine penta acetic acid (DTPA) as an extractant. Exchangeable Kwas determined by ammonium acetate extraction method (Okalebo et al 1993).

Statistical analysis

The agronomic data collected were analyzed statistically through one-way analysis of variance (ANOVA) procedures using JMP 5 [Statistical Analysis System (SAS), 2002]. Least significant difference (LSD) was used for mean comparison among treatments and for correlation analysis between yield and other agronomic components; Statistical Package for the Social Sciences (SPSS) 16 software was used.

Economic Analysis

Economic analysis was conducted based on the [International Center for Maize and Wheat Research (CIMMYT), 1988] approach which utilizes partial budgeting combined with marginal analysis and reveals the economic performance of the treatments based on grain and straw yields of tef. Gross return (yield x price) and net return (gross return – total varying cost) were calculated to carry out marginal rate of return (MRR) analysis which is important for correct evaluation of alternative technologies. The varying fertilizer, seed and labor costs were estimated based on the existing rate of seed and fertilizer purchase and daily labor payment. The yield (grain and straw) harvested from the plots were converted in to hectare basis and the market values of both components were calculated based on the existing market price.

Before undertaking the economic analysis of each treatment, statistical analysis was conducted to compute the reliable yield for each treatment and this economic analysis was conducted for all treatments regardless of their statistical significance. Costs that don't vary among all treatments are not included in the analysis.

In this study, MRR analysis was carried out on both dominated and un-dominated treatments in a stepwise manner starting from control to the other treatments. CIMMYT (1988) and Asumadu et al (2004) provided the minimum rate of return that ranges between 40% and 100%, whereas Farquharson (2006) and Shah et al (2009) suggested minimum rate of return to be 100%, especially for poor farmers in developing countries or for technologies requiring substantial change to a farming system. Accordingly, in this study, 100% marginal rate of return was considered as aguarantee for the farmers to accept a new technology without doubt.

Results and Discussion

Plant height, panicle length and panicle seed weight

It is evident from Table 1 that significantly higher plant height, panicle length and panicle seed weight were found from band application of complete fertilizer under the seed drilling in row at 5 kg ha^{-1}seed rate (T1) followed by the band application of DAP and urea under the seed drilling in row at 5 kg ha^{-1}seed rate (T3); and lower result of all the above parameters was recorded from the control (T5) on both soil types.

However, non significant result for plant height, panicle length and panicle seed weight was found between T1 and T3 for both soils except on Cambisols for panicle seed weight. This shows that sowing method and different seed rate are more important in influencing plant parameter regardless of the fertilizer type. Applying fertilizer close to the seed improves nutrient availability and promotes growth than broadcasting method.

Drill method of sowing tef at low seeding rate was superior over the broadcasted. This corresponds with the finding of Soomro et al (2009) who stated wheat planted by drilling method resulted taller plants than the broadcasted seed. But, this result does not agree with Oyewole et al (2010) who observed non significant effect of sowing method on plant height of rice.

Table 1. Plant height, panicle length and panicle seed weight as affected by the treatments

Treatment	Plant height (cm)		Panicle length (cm)		Panicle seed weight (g)	
	Vertisol	Cambisol	Vertisol	Cambisol	Vertisol	Cambisol
T1	144.93^{a}	140.50^{a}	55.57^{a}	55.33^{a}	1.47^{a}	1.39^{a}
T2	128.80^{b}	127.53^{bc}	51.03^{ab}	50.80^{bc}	0.85^{b}	0.81^{c}
T3	141.17^{a}	133.93^{ab}	53.33^{ab}	52.23^{ab}	1.42^{a}	1.31^{b}
T4	126.67^{b}	122.57^{c}	47.83^{b}	47.73^{c}	0.76^{b}	0.79^{c}
T5	97.10^{c}	85.47^{d}	30.70^{c}	28.43^{d}	0.19^{c}	0.16^{d}
CV	13.7	16.52	19.74	21.21	42.15	51.18
P-Value	**	**	**	**	**	**

Levels not connected by same letter in columns are significantly different at $P < 0.01$. ** Stands significant at $P<0.01$; T1: band application of complete fertilizer under row sowing tef at 5 Kg ha^{-1} seed rate; T2: seed broadcast at 25 Kg ha^{-1} seed rate with complete fertilizer; T3: band application of DAP and urea under row sowing tef at 5 Kg ha^{-1} seed rate; T4: seed broadcast at 25 Kg ha^{-1} seed rate with DAP and urea; T5: tef seed broadcasting at 25 Kg ha^{-1} with no fertilizer (Control treatment).

Tillering and lodging percentage

Significantly higher number of tiller/plant was found in plots treated with T3 (band application of DAP and urea under the row sowing tef at 5 kg ha^{-1}seed rate) preceded by T1 (band application of complete fertilizer under the row sowing tef at 5 kg ha^{-1}seed rate) while the minimum number of tillers was observed from the control in both soils (Table 2). This was because, drilling seed and fertilizer create a good contact between seed and fertilizer, reduce loss and provide nutrient, especially N much better that enhance tiller of tef.

Regardless of the fertilizer type, broadcasting method of sowing has lower tillering capacity than the drill method. This finding is in agreement with the finding of Soomro et al (2009) who indicated maximum tiller capacity of wheat from the drill method of sowing. However, this result contradicts with Oyewole et al (2010) who observed non significant effect of sowing method on tiller formation of rice crop.

Lodging percentage was significantly higher on the plots treated with T2 (broadcast seed at 25 kg ha^{-1} seed rate and complete fertilizer) on both soils. However, the lower lodging percentage was recorded from the control plots. This might be due to the stunted growth of tef caused from poor/absence of nutrition. Unlike the row planted treatments in which lodging was occurred after grain filling stage via sudden wind and heavy rain spray, lodging in the broadcasted treatments has started before the grain filling stage and continued until harvest in both soil types.

Table 2. Impact of the treatments on tillering capacity and lodging

Treatments	Vertisol			Cambisol		
	Tiller/plant	Lodging (%)	RLI (%)	Tiller/plant	Lodging (%)	RLI (%)
T1	13.83^{a}	46.67^{c}	95	13.57^{a}	45.00^{b}	99
T2	3.77^{c}	77.67^{a}	224	3.67^{c}	70.00^{a}	209
T3	11.73^{b}	44.67^{c}	86	11.67^{b}	42.67^{b}	88
T4	3.43^{cd}	73.33^{b}	206	3.53^{c}	67.33^{a}	197
T5	3.13^{d}	24^{d}	-	3.30^{c}	22.67^{c}	-
Significant level	**	**	-	**	**	-

Levels not connected by same letter in the same column are significantly different at $P < 0.01$. ** Stands significant at $P<0.01$; RLI – relative lodging increase from control. T1: band application of complete fertilizer under row sowing tef at 5 kg ha^{-1} seed rate; T2: seed broadcast at 25 kg ha^{-1} seed rate with complete fertilizer; T3: band application of DAP and urea under row sowing tef at 5 kg ha^{-1} seed rate; T4: seed broadcast at 25 kg ha^{-1} seed rate with DAP and urea; T5: tef seed broadcasting at 25 kg ha^{-1} with no fertilizer (Control treatment).

On Vertisols, band application of complete fertilizer under the row sowing tef at 5 kg ha^{-1} seed rate (T2) increased lodging by 224% over the control(T5) whereas band application of DAP and urea under the row sowing of tef at 5 kg ha^{-1}seed rate (T3) increased by 206% (Table 2). In the same way, band application of complete fertilizer under the row sowingtef at 5 kg ha^{-1} seed rate on the Cambisols increased lodging by 209% while band application of DAP and urea under the row sowing of tef at 5 kg ha^{-1}seed rate increased by 197%. In general, relatively lower lodging percentage was measured in the row planted tef at 5 kg ha^{-1}seeding rate than the broadcasted with recommended seed rate, in which both received the same amount and type of fertilizer. This is in agreement with Tefera and Belay (2006) who affirmed that row sowing minimizes lodging. The reason for this might be due to the drilling of the seed in the soil rather than place on the surface help for better establishment of root system. Consequently, it improved the strength of shoot development from the lower population density of the row planted tef. This is conformable with Bedada (2009) who reported lodging index decreases as seeding depth increased from surface broadcast (0 cm) to 3 cm in two locations in Ethiopia, and with Yenesew et al (2011) who reported decreasing the recommended tef seed rate from 25 kg ha^{-1}to 10 kg ha^{-1}increases the capacity of tef shoot to increase its strength and withstand lodging. Therefore, based on the results of this study as well as previous findings it is believed that vulnerability to lodging might be strictly associated with seed rate, sowing method, fertilizer type and application method. Broadcasting tef at seed rate of 25 kg ha^{-1}combined with optimum N fertilization caused tender stalk and weak root system subjected to weather conditions (wind and heavy rainfall) particularly during grain filling stage.

Grain yield, straw yield and harvest index

Tef grain and straw yield were significantly influenced by the combined effect of sowing method at different seed rates and fertilizer type (Table 3). Grain yield of plots on both soils treated with band application of complete fertilizer under row sowing tef at 5 kg ha^{-1}seed rate (T1) was significantly higher than the other treatments involved and this was followed by the band application of DAP and urea under the row sowing tef at 5 kg ha^{-1}seed rate (T3). Broadcasting seed (at 25 kg ha^{-1}seed rate) with complete fertilizer (T2) and broadcasting seed (at 25 kg ha^{-1}seed rate) with DAP and urea (T4), on the other hand, gave non-significant results on both soil types. These observations revealed that the combined effect of sowing method and plant population regardless of the fertilizer type played vital role in influencing grain yield. Straw yield follows the same statistical output except that T3 showed significantly different straw yield compared to T4.

The grain yield obtained from row planted tef at low seeding rate (Table 3) irrespective of the fertilizer type is more than two times higher than the national and regional (1.15 Mg ha^{-1}) average tef productivity during 2010/11 (CSA 2011). The possible reasons for this yield increment could be due to the low seed rate, yield potential of the variety, efficient resource utilization (sunlight, moisture and nutrients) and relatively reduced lodging problem of the row planting. Fufa et al (2001) reported that there is an ample chance to increase tef productivity by integrating high yielding varieties and improved management practices.

The superiority of complete fertilizer over the DAP and urea fertilizers treatment at the same sowing method and sowing rate might be due to the addition of new nutrient from the complete fertilizer which might facilitate the uptake of other essential plant nutrients.In the same manner, straw yield of tef was significantly affected by the combined effect of sowing method and fertilizer type (Table 3). The highest straw yield on both soil types was measured from the band application of complete fertilizer under the row sowing of tef at 5 kg ha^{-1} seed rate.

'Quncho' tef variety was treated with band application of complete fertilizer under drill seed in row at 5 kg ha^{-1} seed rate(T1). On the other hand, row sowing method of tef at 5 kg $ha^{-1}$and band application of complete fertilizer beneath the tef seed (T1) brought an increment of about 220% (on Vertisols) and 203% (on Cambisols) over the current national average yield (about 1.15 Mg ha^{-1}). Comparably, 'Quncho' planted in row at 5 kg ha^{-1} complement with DAP and urea fertilizers banded in line (T3), brought an increment of about 186% (on Vertisols) and 160% (on Cambisols) over the current national average yield of tef indicated above.

Table 3. Results for harvest index, grain yield (Mg ha^{-1}) and straw yield (Mg ha^{-1})

Experimental soil	Treatment	Grain Yield (Mg ha^{-1})	Straw Yield (Mg ha^{-1})	Harvest Index
Vertisol	T1	3.66 ± 0.049^{a}	9.5 ± 0.044^{a}	0.28 ± 0.002^{a}
	T2	2.05 ± 0.035^{c}	6.59 ± 0.054^{c}	0.24 ± 0.002^{b}
	T3	3.24 ± 0.037^{b}	8.87 ± 0.028^{b}	0.27 ± 0.002^{a}
	T4	1.86 ± 0.039^{c}	6.15 ± 0.049^{d}	0.23 ± 0.003^{b}
	T5	0.87 ± 0.036^{d}	3.74 ± 0.077^{e}	0.19 ± 0.003^{c}
	CV	44.58	30.68	13.18
	P-value	**	**	**
Cambisol	T1	3.46 ± 0.097^{a}	9.21 ± 0.11^{a}	0.27 ± 0.004^{a}
	T2	2.06 ± 0.033^{c}	6.35 ± 0.081^{c}	0.22 ± 0.001^{b}
	T3	2.96 ± 0.063^{b}	8.32 ± 0.051^{b}	0.27 ± 0.004^{a}
	T4	1.99 ± 0.045^{c}	5.9 ± 0.099^{c}	0.21 ± 0.003^{b}
	T5	0.70 ± 0.003^{d}	3.42 ± 0.093^{d}	0.17 ± 0.001^{c}
	CV	44.05	31.58	23.51
	P-value	**	**	**

Levels not connected by same letter in the same column are significantly different at P < 0.01. ** Stands for significance at (P < 0.01) level. T1: band application of complete fertilizer under row sowing tef at 5 kg ha^{-1} seed rate; T2: seed broadcast at 25 kg ha^{-1} seed rate with complete fertilizer; T3: band application of DAP and urea under row sowing tef at 5 kg ha^{-1} seed rate; T4: seed broadcast at 25 kg ha^{-1} seed rate with DAP and urea; T5: tef seed broadcasting at 25 kg ha^{-1} with no fertilizer (Control treatment).

As the results indicated on Figure 3, the relative yield increment of the treatments (T1, T2, T3 and T4) over the control treatment was by 320%, 135%, 275%, 144% (on Vertisols) and 396%, 195%, 235%, 186% (on Cambisols) for the respective treatments. This reflects broadcast method of sowing tef with no fertilizer application reduced tef yield productivity by more than 100%.

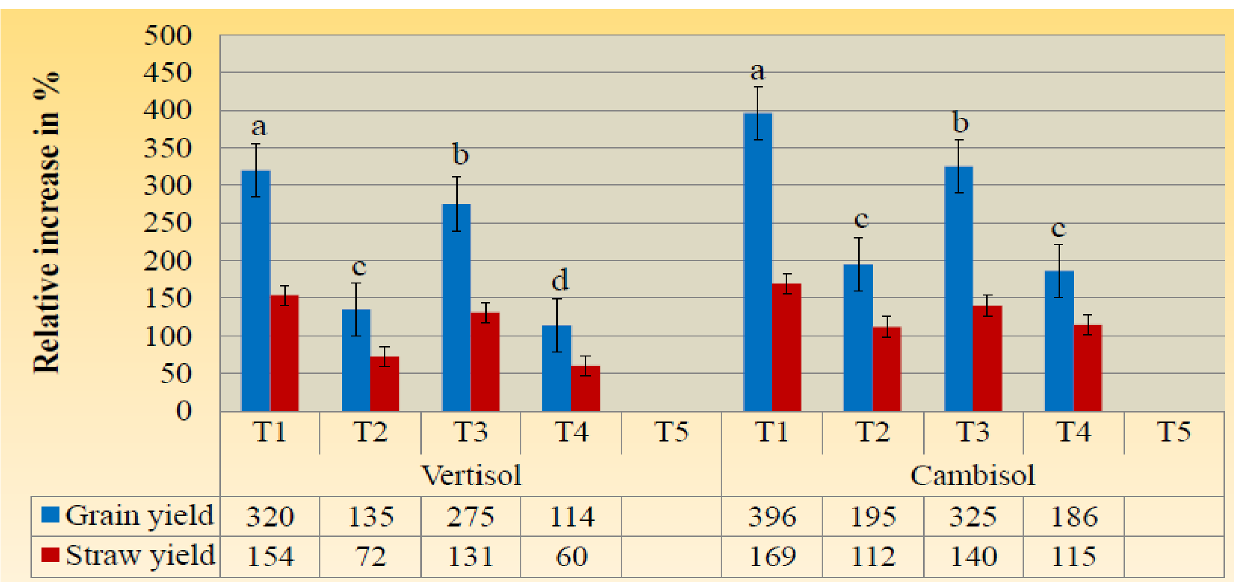

Figure 3. Relative yield increase over the control (T5)

Highest harvest index (HI) was obtained from row planted tef at 5 kg ha^{-1} seed rate with complete fertilizer and the lower value from the control in both sites. The low HI could be associated with the absence of nutrients in the soil available for the crop. The absence of nutrient retards growth and finally leads to fail to produce well matured grains before the rainfall ceases.

The variation in agronomic characters in response to the sowing method and seeding rates of the treatments that receive the same fertilizer might be due to dense population, uneven stand and space~~;~~ which led to lodging and competition for moisture, nutrient and sunlight. Comparable yield superiority of the complete fertilizer over the DAP and urea source of fertilizer on both sowing methods was observed in these trials~~;~~ and this could be associated with the additional nutrients involved in the complete fertilizer (K, S, Mg and Zn) other than N and P. In addition to this, Havlin et al. (2005) reported that application of P and Zn nutrients in soils which are marginally deficient in P and Zn improves crop yield, indicating positive interaction of P and Zn. However, high P availability or application of P fertilizer alone could induce Zn deficiency in plants, commonly known as P – induce Zn deficiency (Cakmak and Marschner 1987). Thus, application of Zn containing P fertilizer on Zn and/or P deficient soils could improve tef yield. Positive and higher response to complete fertilizer is an indication of the soil's deficiency on the nutrients like N, P, K, S, Mg, and Zn.

Generally grain yield, straw yield and HI were significantly ($P<0.01\%$) affected by the combined effect of sowing method at different seed rates and fertilizer sources in both experimental fields~~;~~ and the maximum values of these parameters were recorded from the band application of complete fertilizer under the row sowing at 5 kg ha^{-1} seed rate and secondly, band application of DAP and urea under the row sowing of tef at 5 kg ha^{-1} seed rate in both experimental soils.

Correlation of yield and other agronomic parameters

Strong significant positive correlation of grain yield with all the agronomic parameters was observed except with lodging index in both trial sites~~;~~ indicating that grain yield could invariably increase by increasing these attributes (Table 4 and 5). This result was supported by the recent findings of Chanyalew (2010) on 18 tef genotypes, which reported that grain yield was significantly and positively correlated with plant height, panicle length, shoot biomass, plant seed weight, and HI. Similarly, it was reported that tef grain yield was highly positively correlated with plant seed weight and shoot biomass (Hundera et al 1999 and Tefera et al 2003). Correspondingly in wheat, Burio et al (2004), Kotal et al (2010) and Abd El-Lattief (2011) reported that grain yield was positively associated with plant height and straw yield. Girmay et al (2009) also reported that on Vertisols, wheat grain yield with spike length while straw yield with plant height were strongly correlated.

On the Vertisols experimental soil, lodging index (Table 4) showed positive significant association with panicle length only~~,~~ but with the other attributes, no significant correlation was found. On Cambisols positive significant correlations of lodging index with HI, plant height and panicle length (Table 5) were found in conformity with Yu et al (2007) who demonstrated that lodging index showed highly significant positive correlations with plant height, panicle length, panicle seed weight, grain yield and shoot biomass yield, thus, indicating that the high yielding lines tended to lodge more. Nevertheless, positive but non-significant association was obtained between lodging index and grain yield, straw yield~~,~~ and panicle seed weight in both field trials. On the other hand, negative and insignificant correlation was found between lodging and tiller formation in both sites indicating that tiller formation can minimize lodging.

On the Vertisol experimental soil, lodging index (Table 4) shows positive significant association with panicle length only, but with the other attributes no significant correlation was found. On Cambisol positive significant correlation of lodging index with harvest index, plant height and panicle length (Table 5) was found in conformity with Yu et al (2007) who demonstrated that lodging index showed highly significant positive correlations with plant height, panicle length, panicle seed weight, grain yield and shoot biomass yield, thus, indicating that the high yielding lines tended to lodge more. Nevertheless, positive but non-significant association was obtained between lodging index and grain yield, straw yield, and panicle seed weight in both field trials. On the other hand, negative and insignificant correlation was found between lodging and tiller formation in both sites indicating tiller formation can minimize lodging.

Table 4. Correlation coefficients of grain yield with other agronomic parameters on Vertisols.

Paraeters	GY	SY	HI	PH	PL	PSW	Tiller	Lodging
GY	1	0.996**	0.987**	0.944**	0.862**	0.989**	0.932**	0.096^{ns}
SY		1	0.992**	0.964**	0.896**	0.995**	0.900**	0.174^{ns}
HI			1	0.975**	0.901**	0.987**	0.870**	0.228^{ns}
PH				1	0.959**	0.965**	0.767**	0.398^{ns}
PL					1	0.903**	0.639*	0.535*
PSW						1	0.886**	0.186^{ns}
Tiller							1	-0.268^{ns}
LI								1

*, ** significantly different at 5% and 1% probability levels, respectively.'ns' indicates not significant. GY: grain yield; SY: straw yield; HI: harvest index; PH: plant height; PL: panicle length; PSW: panicle seed weight.

Generally in both sites weak but positive and insignificant association existed between lodging and grain yield whereas, studies in tef in other areas have shown strong and positively significant correlations between lodging and grain yield (Hundera et al 1999; Tefera and Ketema, 2001; Tefera et al 2003; Yu et al 2007).

Table 5. Correlation coefficients of grain yield with other agronomic parameters on Cambisols.

Parameters	GY	SY	HI	PH	PL	PSW	Tiller	Lodging
GY	1	0.961**	0.985**	0.912**	0.915**	0.993**	0.869**	0.274^{ns}
SY		1	0.921**	0.978**	0.977**	0.957**	0.704**	0.520*
HI			1	0.878**	0.883**	0.991**	0.896**	0.199^{ns}
PH				1	0.991**	0.918**	0.601*	0.623*
PL					1	0.918**	0.611*	0.617*
PSW						1	0.858**	0.283^{ns}
Tiller							1	-0.234^{ns}
LI								1

*, ** significantly different at 5% and 1% probability levels, respectively. 'ns' indicates not significant. GY: grain yield; SY: straw yield; HI: harvest index; PH: plant height; PL: panicle length; PSW: panicle seed weight. T1: band application of complete fertilizer under row sowing tef at 5 kg ha^{-1} seed rate; T2: seed broadcast at 25 kg ha^{-1} seed rate with complete fertilizer; T3: band application of DAP and urea under row sowing tef at 5 kg ha^{-1} seed rate; T4: seed broadcast at 25 kg ha^{-1} seed rate with DAP and urea; T5: tef seed broadcasting at 25 kg ha^{-1} with no fertilizer (Control treatment).

The overall merits of row sowing tef at low seeding rate (5 kg ha^{-1}) over that of broadcasting method at a recommended seed rate (25 kg ha^{-1}) irrespective of the fertilizer type used was found due to lower plant population density, line placement of seed and and application of fertilizer in the soil at desired depth instead of on the soil surface which affords uniform seed distribution and germination, optimum spacing for efficient resources (nutrient, moisture, sunlight) utilization responsible to improve root crown establishment, tillering capacity, longer plant height with vigour shoot development and relatively lower susceptibility to lodging. The advantage of row sowing method is not only to improve tef yield but also to save the seed.

In general, all the above mentioned agronomic parameters have direct contribution in enhancing tef yield. Plant height (Yu et al 2007), tillers per plant, panicle weight, and shoot biomass (Tefera 1993; Chanyalew et al 2006, Chanyalew et al 2009) have reported as an important determinants of yield. However, even with good crop management and appropriate fertilization, lodging is the major bottleneck (Ketema 1983, 1997 and Yu et al 2007) to increase tef productivity. In addition to yield losses, lodged plant also poses a great problem for harvesting (Hewan and Fujimura 2010; Assefa et al 2011) which lead to economic losses.

Economic performance

Row sowing method of tef together with complete fertilizer application has improved agronomic yield (grain and straw) in the study areas. However, it should be aided by economic analysis before giving any recommendations. Result of economic analysis for the treatments using partial budget method (Table 6) showed that net income on Vertisols was higher in the row sowing treatments~~,~~ than the broadcast treatments. However, net field income different from profit because in partial budget analysis only costs that vary are included, excluding the other production costs. Thus, based on the size of the net field income it would be difficult to select the economically preferred treatment. For this reason, in order to compare each treatment, a marginal analysis was done based on the information on net field benefits and costs that vary (Table 7).

Considering the comparison with control (Table 7), the MRR on Vertisols were 596%, 249%, 815%, and 391% for T1, T2, T3, and T4, respectively. The corresponding values on Cambisols were 586%, 342%, 733%, and 612%. The MRR from broadcasted treatments (T2 and T4) was lower than the row sowing treatments (T1 and T3) in both sites. This result was similar that of Abd El-Lattief (2011) who found higher return from drill sowing method than the broadcasted wheat. The 733% marginal rate of return indicated that the income obtained from application of DAP and urea on tef cultivation in row with low seed rate (5 kg ha^{-1}) is more than 7 times higher than its cost of production.

The stepwise comparison (dominant analysis) between successive treatments depicted that treatments which received DAP and urea fertilizers in both sowing methods have higher MRR (Table 7). On Vertisols, by changing sowing method of tef from broadcast to drill while in uniform DAP and urea application (T3), farmers can recover 1 birr plus an extra birr 23.44 Birr/ha in net benefit for each 1 Birr/ha on average invested. On the other hand, changing from drilled tef sowing with DAP and urea application (T3) to broadcast tef sowing with complete fertilizer application (T2, dominated)–makes farmer to loss 15.62 Birr/ha for 1 birr invested. MRR on Cambisols is in consistence with this result. Considering the assumption of minimum acceptable MRR by farmers as 100% to adopt a new technology in this study, all treatments except broadcast sowing with complete fertilizer (T2) were acceptable, but the most economically profitable treatment was band application of DAP and urea under row sowing of tef at 5 kg/ha seed rate (T3) followed by broadcasting of tef seed at 25 kg/ha with DAP and urea

(T4) in both trial locations. Therefore, though the net return of DAP and urea fertilization seemed inferior to the complete fertilizer in both sowing methods. Besides, in view of economic analysis, DAP and urea fertilizer application was economically profitable than complete fertilizer in both sowing methods. On the other hand, superiority of drill over broadcast treatments was observed even if they received the same fertilizer type and amount.

Table 6. Partial budget analysis of the treatments

Experimental soils	Return and Cost items			Treatment T1	T2	T3	T4	T5
Vertisol	Gross return (Birr/ha)	Grain		34255	19210	30600	17425	8160
		Straw		7329	5082	6846	4746	2961
		Total		41584	24292	37446	22171	11121
	Costs (Birr/ha)	Purchasing & transportation	seed	58	288	58	288	288
			fertilizer	3642	3642	2106	2106	-
		Daily Labor		2789	1956	2822	1967	1822
		Total varying cost		6489	5886	4986	4361	2110
		Change in cost (ΔC)		4379	3776	2876	2251	-
	Net return (income)			35095	18406	32460	17810	9011
Cambisol	Gross return (Birr/ha)	Grain		32470	19295	27795	18700	5445
		Straw		7105	5600	6328	5670	2639
		Total		39575	24895	34123	24370	8084
	Costs (Birr/ha)	Purchasing & transportation	seed	58	288	58	288	288
			fertilizer	3642	3642	2106	2106	-
		Daily Labor		3458	2444	3527	2458	2278
		Total costs		7158	6374	5691	4852	2566
		Change in cost from control		4592	3808	3125	2286	-
	Net return (income)			32417	18521	28432	19518	5518

- Daily labor cost on the Vertisol site was 50 Birr/day; on Cambisol site was 40 Birr/day. Cost for DAP, urea, Yara Milla Cereal and TSP were =1171; 935; 1250; 1171 Birr/100kg respectively. Price for grain 8.5 birr/kg; and for straw 0.7 birr/kg. Cost per plot was converted to per hectare base. Current One US Dollar = 17.46 Birr.T1: band application of complete fertilizer under row sowing tef at 5 Kg ha^{-1} seed rate; T2: seed broadcast at 25 Kg ha^{-1} seed rate with complete fertilizer; T3: band application of DAP and urea under row sowing tef at 5 Kg ha^{-1} seed rate; T4: seed broadcast at 25 Kg ha^{-1} seed rate with DAP and urea; T5: tef seed broadcasting at 25 Kg ha^{-1} with no fertilizer (Control treatment).

Table 7. Marginal analysis of the treatments

Return & costs	Comparison with control T1	T2	T3	T4	T5	Step wise comparison (dominance analysis) T5	T4	T3	T2	T1
Vertisol										
Gross return	41584	24292	37446	22171	11121	11121	22171	37446	24292	41584
Total varying cost	6489	5886	4986	4361	2110	2110	4361	4986	5886	6489
Net return	35095	18406	32460	17810	9011	9011	17810	32460	18406	35095
Net income over control	26084	9395	23449	8799	-	-	8799	23449	9395	26084
MRR (%)	596	249	815	391	-	-	391	2344	-1562[d]	175
Cambisol										
Gross return	39575	24895	34123	24370	8084	8084	24370	34123	24895	39575
Total varying cost	7158	6374	5691	4852	2566	2566	4852	5691	6374	7158
Net return	32417	18521	28432	19518	5518	5518	19518	28432	18521	32417
Net return over control	26899	13003	22914	14000	-	-	1400	22914	13003	26899
MRR (%)	586	342	733	612	-	-	612	1063	-1451[d]	267

Nonetheless, tef is an economically miracle cereal crop. Because, whatever sowing method and/or fertilizer type be applied, tef cultivation is economically profitable since tef producers can gain income to cover the total costs of production from the straw yield only and so the grain yield will be a profit (Table 6).

Conclusion and Recommendation

Conclusion

Band applications of compound fertilizer integrated with sowing methods at different seeding rates appreciably affected all the studied agronomic parameters and resulted significant variation, with low to high magnitude of variability. The significant effect observed were: 1) fertilizer application increased yield but was higher when planted on row at 5 kg ha^{-1} seed rate. 2) All the improved treatments performed better than the control. The low response of the control treatment in all agronomic parameters can be attributed to the low fertility status. The overall dramatically boosted grain and straw yield obtained from tef sown in row at low seeding rate (5 kg ha^{-1}) complemented with different fertilizer applications was due to the positive effect on plant height, panicle length, panicle seed weight, tiller number, and relatively low vulnerability to lodging caused by the low plant population density and band application method of fertilizers under the row sowing tef in the soil instead of on the soil which helps for efficient resource utilization.

Recommendation

Yield enhancement through the band application of complete fertilizer under row sowing of tef at low seeding rate (5 kg ha^{-1}) indicates the major tef yield limiting factors in the study area were micro and macro nutrients deficiency, broadcast method of sowing at high seed rate and susceptibility to lodging. Thus, improved input management practices such as row sowing of tef at low seed rate integrated with appropriate fertilizer application are very crucial to enhance tef production and productivity. Row sowing methods relatively resist lodging incidence than the broadcast sowing method. Yet, further solutions are also very important to minimize lodging effect on tef. Althoughclaiming economic benefits based on data obtained from small plots of one year experiment is doubtful, from this preliminary study on two different soil types band application of DAP and urea fertilizers along with the row sowing tef at 5 kg/ha provides the most economically profitable values of grain and straw. Finally, the study calls for in depth agronomic and economic investigations on different rates of Yara Mill Cereal (complete fertilizer) against different rates of DAP and urea on various tef varieties under different seed rates and sowing methods.

Acknowledgment

The research reported in this thesis was funded by the Ethiopian Agricultural Transformation Agency (ATA). The authors would like to acknowledge the financial support by ATA and we want to express our sincere gratitude and appreciation to those who provided us constructive advice and valuable comments throughout the work.

References

Abd El-Lattief EA (2011): Bread wheat (*Triticum aestivum* L.) productivity and profitability as affected by method of sowing and seeding rate under Qena environment. *Asian Journal of Crop Science* 3(4): 188-196.

Alemneh D (2003): Integrated natural resources management to enhance food security: The case for community-based approaches in Ethiopia.Food and Agriculture Organization of the United Nations, Rome, Italy.

Assefa K, Aliye S, Belay G, Metaferia G, Tefera H and Sorrells M E (2011): *Quncho*: The first popular tef variety in Ethiopia, *International Journal of Agricultural Sustainability*, 9:1, 25-34

Asumadu H, Sallah YK, Boa-Amponsen PB, Allou J, Manu-Adunung and Osei-Bounsu (2004): On-farm evaluation and promotion of quality protein maize hybrids in Ghana. *In:* African crop science proceedings, Vol 4. *Africa crop science society*, pp. 358-364.

Bedada W (2009): Growth, lodging and yield of tef (*Eragrostis tef)* as influenced by seed size and depth of sowing. unpublished M.Sc. Thesis, Haramaya University, Haramaya, Ethiopia.

Bereket H, Stomph T and Hoffland E (2011). Tef (*Eragrostis tef*) production constraints on Vertisol in Ethiopia: farmers' perceptions and evaluation of low soil zinc as yield-limiting factor, *Soil Science and Plant Nutrition*, 57:4, 587-596.

Bouyoucos GL (1962). Hydrometer method for making particle size analysis of soils. *Agronomy Journal* 53: 464 – 465.

Burio UA, Oad FC and Agha SK (2004): Correlation coefficient (r) values of growth and yield components of wheat under different nitrogen levels and placements. *Asian J. of Plant Sci.*, 3: 372-374.

Cakmak I, and Marschner H (1987): Mechanism of phosphorous-induced zinc deficiency in cotton. III. Changes in physiological availability of zinc in plants. Physiol. Plant. 70: 13-20.

Chanyalew S, Tefera H and Singh H (2006): Correlation and path coefficient analysis of yield related traits in recombinant inbred lines of tef (*Eragrostis tef*). J Genet and Breed., 60: 209-216.

Chanyalew S Tefera H and Singh H (2009): Genetic variability, heritability and trait relationships in recombinant inbred lines of tef[*Eragrostis Tef* (Zucc.) Trotter]. Res J Agri Biol Sci., 5(4): 474-479.

Chanyalew S (2010): Genetic Analyses of Agronomic Traits of Tef (*Eragrostis tef*) Genotypes.*Research Journal of Agriculture and Biological Sciences*, 6(6): 912-916, 2010 INSInet Publication.

CIMMYT (International Center for Maize and Wheat Research)(1988): From agronomic data to farmer recommendations: an economics training manual (completely revised edition). CIMMYT, Mexico, DF, pp 9-38.

CSA (Central Statistical Agency) (2011): Agriculture in figures: key findings of the 2008/09 – 2010/11 agricultural sample surveys for all sectors and seasons. October, 2011. Addis Ababa.

Deckers T Yizengaw T Negeri A and Ketema S (2001): Eragrostis tef (Zucc.) Trotter. *In*: Raemaekers, R.H. (Ed.) Crop production in tropical Africa. Directorate General for International Co-operation (DGIS): Ministry of Foreign Affairs, External Trade and International Co-operation, Brussels, Belgium.

EFMA (European Fertilizer Manufacturers Association) (2004): Understanding Nitrogen and its use in agriculture. Avenue E. van Nieuwenhuyse 4, B-1160 Brussels, Belgium [Online]. Available from: www.efma.org [Date of accessed 15/07/2011].

FAO/UNESCO (1977): Soil map of the world, vol 6.Africa. UNESCO, Paris.

Farquharson RJ (2006).Production response and input demand in decision making: nitrogen fertilizer and wheat growers. Australasian Agribusiness Review - Vol.14 – 2006 Paper #5.

Fufa H Tesfa B Hailu T Kibebew A Tiruneh K Aberra D and Ketema K (2001): Agronomy research in tef. In: Hailu, T., Getachew, B. and Mark, S. (eds), Narrowing the rift. Tef research and development. Proceedings of the International Workshop on Tef Genetics and Improvement, 16-19 Oct 2000, Debre Zeit, Ethiopia, pp. 167-176.

Girmay G Mitiku H and Singh BR (2009): Agronomic and economic performance of reservoir sediment for rehabilitating degraded soils in Northern Ethiopia. *Nutr Cycl Agroecosyst* (2009) 84:23-38.

Habtegebrial K and Singh BR (2006): Effects of timing of nitrogen and sulphur fertilizers on yield, nitrogen, and sulphur contents of tef (*Eragrostis tef* (Zucc.) Trotter). *Nutr Cycl Agroecosyst*, 75:213–222

Haileselassie F (2006): Effects of N, P, K fertilizer rates on yield and yield components of tef on vertisol of Laelay Michew. Unpublished M.Sc. Thesis, Mekelle College of Agriculture and Natural Resource, Mekelle University, Mekelle, Ethiopia.

Havlin JL Beaton JD Tisdale SL and Nelson WL (2005): Soil Fertility and Fertilizers: An Introduction to Nutrient Management: 7th Ed. Prentice Hall, New Jersey.

Hewan DD and Fujimura T (2010): Mapping QTLs related to plant height and root development of Eragrostis tef under drought. *Journal of Agricultural Science*; Vol. 2, No. 2, June 2010. Tsukuba, Japan.

Hundera F Tefera H Assefa K and Kefyalew T (1999): Genetic variability and correlation of morpho-agronomic characters in tef landraces. *Trop Sci*., 39: 140-146.

Ketema S (1983): Studies of lodging, floral biology and breeding techniques in tef. [*Eragrostis tef* (Zucc.) Trotter]. PhD Thesis, London University, London, U.K.

KetemaS (1997): Tef: [*Eragrostis tef (Zucc.)*Trotter]. Promoting the conservation and use of underutilized and neglected crops, 12. Institute of plant genetics and crop plant research, Gatersieben / International plant genetics resource institute, Rome, Italy.

Khee C (2001): Determination of total N: Current protocol in food analytical chemistry. Texas A and M University College Station, Texas, USA.

Kotal BD Das A and Choudhury BK (2010): Genetic Variability and Association of Characters in Wheat (*Triticum aestivum* L.). *Asian Journal of Crop Science*, 2: 155-160.

Kowalenko CG (1985): A modified apparatus for quick and versatile Sulphate sulfur analysis using hydriodic acid reduction. Commun, Soil Sci. Plant Anal.

Lindsay WL and Norvell WA (1978). Development of a DTPA soil test for Zinc, iron, manganese and copper. Soil Sci. Soc. Am. J.

McCauley A Jones C and Jacobsen J (2009): Commercial fertilizer and soil amendment: A self-study course from Montana State University Extension Continuing Education Series. Nutrient management module-10. Montana State University-Bozeman.

Okalebo JR Guathua KW and Woomer PL (1993): Soil laboratory methods and plant analysis. Working Manual. Karhsobf. Nairobi.Kenya.pp55.

Olsen S and Sommer L (1982): Phosphorus method for soil analysis; part 2. Chemical and microbiological properties. *ASA Monograph number* 9:403 – 430.

Oyewole CI Ajayi O and Ojuekaiye RO (2010): Evaluation of yields of seven upland rice (*Oryza sativa*) cultivars sown by three methods in Anyigba, Kogi State, Nigeria.*African Journal of Agricultural Research Vol.* 5(16), pp. 2089-2096 [Online]. Available from: http://www.academicjournals.org/AJAR [Date of accessed: 28/09/2011].

Peach M (1965):. Hydrogen-ion activity. In Black, C.A. (Ed). Methods of soil analysis, Part 2, Chemical and microbiological properties; 9, *Amer. Soc. Agron*. Madison, Wisconsin. pp. 914-925.

Plaza S Bossolini E and Zerihun Tadele (2009): Significance of genome sequencing for African orphan crops: The case of tef. *ATDF Journal* Volume 6, Issue ¾.

Sahlemedhin S and Taye B (Eds) (2000): Procedure for soil and plant analysis: National Soil Research Center, Ethiopia Agricultural Research Organization. Technical paper No 74; Addis Ababa, Ethiopia.

Statistical Analysis System (SAS) (2002): Statistical Analysis System (SAS) Institute Inc., SAS Campus Drive, Gary, NC, USA.

Shah H Sharif M Majid A Hayat U and Munawar A (2009): From experimental data to farmer recommendation: An economic analysis of on-farm trial of UMMB feed for milking animals in rain-fed Pothwar, Pakistan. *Livestock Research for Rural Development. Volume 21, Article #117[online]*. Available from: http://www.lrrd.org. [Date of accessed: 3/4/2012].

Soomro UA Rahman MA Odhano EA Gul S and Tareen AQ (2009): Effects of sowing method and seed rate on growth and yield of wheat (*Triticum sativum*). *World Journal of Agricultural Sciences* 5: 159-162

Tefera H (1993): Modernization of tef (*Eragrostis tef*) improvement with reference to genetics andtissue culture. Ph.D. Thesis, University of London,Wyes College, UK.

Tefera H Assefa K and Belay G (2003): Evaluation of interspecific recombinant inbred lines of *E. tef* x *E. pilosa*. *J Genet and Breed*., 57: 21-30.

Tefera H and Belay G (2006): *Eragrostis tef* (Zuccagni) Trotter. *In:* Brink, M. and Belay, G. (Eds), 2006. Plant resource of Tropical Africa 1. Cereals and pulses. PROTA Foundation, Wageningen, Netherlands, pp289.

Tefera H and Ketema S (2001): Production and importance of tef in Ethiopian agriculture. *In:* Hailu, T., Getachew, B. and Mark, S. (Eds), Narrowing the rift: Tef research and development. Proceedings of the International Workshop on Tef Genetics and Improvement, 16-19 Oct 2000, Debre Zeit, Ethiopia, pp. 191-200.

Tekalign M Teklu E and Balesh T (2001). Soil fertility and plant nutrition research on tef in Ethiopia. *In:* Hailu, T., Getachew, B. and Mark, S. (Eds), Narrowing the rift: Tef research and development. Proceedings of the International Workshop on Tef Genetics and Improvement, 16-19 Oct 2000, Debre Zeit, Ethiopia, pp. 191-200.

Walkley A and Black CA (1934): An examination of degtjareff method for determining soil organic matter and proposed Chromic acid Titration method. *Soil science 37:29-38.*

Yenesew MY Schultz B Abraham MH and Teklu E (2011). Optimizing tef productivity in water stressed region of Ethiopia. International Commission on Irrigation and Drainage, ICID 21st Congress, Tehran, October 2011.

Yu JK Graznak E Breseghello F Tefera H and Sorrells ME (2007): QTL mapping of agronomic traits in tef [*Eragrostis tef* (Zucc.) Trotter]. *Bio Med Central Plant Biology*: **7**: 30.

Evaluation of Blended (NPSZnB) Fertilizer Rate on Yield and Yield Components of Tef under Rain-fed Condition in Medebay Zana and Tahtay Koraro

Tsadik Tadele*, Tewolde Berhe, Kinfe Tekulu, Geberesemaeti Kahsu, Weldegebrel Gebrehiwet, Goitom Aregawi, Solomon Mebrahtom, Tarekegn Yibabie and Samrawit Mebrahtu

[*,] Tigray Agricultural Research Institute, Shire Soil Research Centre, P.O. Box 40, Shire, Ethiopia;
Correspondence author: tsadiktadele27@yahoo.com

Abstract

Despite of its economic importance, tef productivity is low due to low soil fertility as result of intensive soil erosion and long history of cultivation. Therefore, a field experiment was carried out on a farmer's field in Medebay zana and Tahtay koraro Woredas (Adekemalk and Beles Kebelle) during the 2017 and 2018 main cropping seasons to evaluate the levels of NPSZnB blended fertilizer on yield and yield components of tef. The treatments consisted of seven levels of NPSZnB (0, 50, 100, 150, 200, 250 and 300) kg ha^{-1}and blanket recommended NP (64 N: 46 P_2O_5) kg ha^{-1}. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Analysis of the data revealed that days to 50% heading, plant height, number of productive tillers per plant, straw yield, grain yield and harvest index (HI) resulted significant difference over the control plot at both Woredas. However, days to 90% physical maturity and head length (panicle length) at Medebay zana Woreda and HI at Tahtay koraro have no significant difference among treatments. Evnthough, there was no significant difference among treatments, numerically the highest straw yield was recorded from 300 and 250 kg ha^{-1} of NPSZnB in Medebay Zana and Tahtay Koraro Woreda, respectively. On the other hand, the highest grain yield (2165.3 kg ha^{-1}and 1996.6 kg ha^{-1}) was obtained as a result of 200 kg ha^{-1} and 250 kg ha^{-1} of NPSZnB. Thus, application of 50 kg blended NPSZnB ha^{-1} with N adjusted to 64 kg N ha^{-1} is economically beneficial as compared to the other treatments in Medebay zana and Tahtay koraro Woredas.

Keywords: NPSZnB, Tahtay koraro, Medebay zana, Tef and Yield

Introduction

Tef has got both cultural and economic value for Ethiopian farmers with more than six million households' life depending on the production of tef. It is a daily staple food for about 57.20 million people of Ethiopia, and this accounts for more than 64% of the total population of the country (ATA, 2013b). According to Tarekegne (2010), factors that are contributing to low productivity of the crop is as a result of plant lodging, a decline in the soil fertility due to high soil erosion, unbalanced chemical fertilizer application, method of planting problems and others.

There are several factors that lead to nutrient deficiency in soil resulting in low production. Nutrient mining due to sub optimal fertilizer use coupled with agronomically unbalanced fertilizer uses have favored the emergence of multi nutrient deficiency in Ethiopian soils (Asgelil et al., 2007) which in part explain fertilizer factor productivity decline and stagnant crop productivity conditions encountered. In Ethiopia, phosphorus (P) as di-ammonium phosphate (DAP) and nitrogen (N) as urea have been the only chemical fertilizers used for crop production with initial understanding that N and P are the major limiting nutrients of Ethiopian soils (Bekabil and Hassan, 2006). However, plant growth and crop production require an adequate supply and balanced amounts of all nutrients.

To increase production of cereal crops, use of proper amounts of all essential nutrients is important. Fertilizers are efficient exogenous source of plant nutrients (Akram et al., 2007). Consequently, adding micronutrients to NP fertilizer can be increase fertilizer use efficiency and grain yield for different cereal crops (Malakouti, 2008). The widespread deficiency of N, P and sulfur (S) nutrients is followed by Zinc (Zn) and boron (B) deficiency~~,~~ which accounts almost 50% of the nutrient deficiency in the world soils used for cereal production (Gibbson, 2006). The micronutrient deficiency appears to be the most widespread and frequent micronutrient deficiency problems in crops which result in severe losses in yield and nutritional quality particularly in areas of cereal production under rain fed production in many parts of the world (Alloway, 2008). The soil fertility mapping project in Ethiopia reported the deficiency of K, S, Zn, B and Cu in addition to N and P in major Ethiopian soils and N, P, S, Zn and B particularly in the study area [Ethiopian Soil Information System (Ethio SIS), 2014]. Balanced fertilizers containing N, P, S, B, Fe and Zn in blend form have been recommended to solve site specific nutrient deficiencies and thereby increase crop production and productivity (ATA, 2014). The major recommended blended fertilizers for Tigray region are NPS, NPSB, NPSZn, NPSZnB, NPSFeZn and NPSFeZnB. Though potassium (K) was part of the previous blend fertilizer, recently it was suggested to be applied based on soil test result.

Except the blanket recommendation of N and P, the effect of other fertilizers on yield components, yield, and overall performance of tef are unknown, even though new blended fertilizers such as NPSZnB (17 N – 34 P_2O_5 + 7S + 2.2Zn + 0.67B) (ATA,2014) are currently being used by the farmers in the study area. In addition to this, the amount of N in the blended

NPSZnB is small as compared to the requirement of tef. Thus, there is a need to supplement with nitrogenous fertilizer in the form of urea. Thus, there is a need to develop site specific fertilizer rate recommendation to increase production and productivity of tef. Therefore, this study was undertaken with the objectives of evaluating the effect of rates of blended NPSZnB fertilizers on yield and yield components of tef and identifying the economically feasible rates of blended NPSZnB and N fertilizers for high yield of tef.

Materials and Methods

Description of the study area

Field experiments were carried out for two consecutive seasons (2017 and 2018) under rainfed conditions on three selected farmer's fields on each season at Medebay zana (Adekemalk Kebelle) and Tahtay koraro (Beles Kebelle) WoredaWoredas of northwestern Tigray, Northern Ethiopia. The two Woredas are the basic representative for the mid lands of North Western zone of Tigray Tegional State. The experimental site for Medebay zana was extends from 14^0 06' 10.608" N to 14^0 04' 12.246" N latitude, 38^0 27' 43.75" E to 38^0 25' 36.960" E longitudes and an altitude of 1977 to1986 m.a.s.l.Sites for Tahtay Koraro extends from 14^0 04' 36.36" N to 14^0 01' 48.7" N latitude, 38^0 23' 11.718" E to 38^0 22' 29.5" E longitudes and an altitude of 1958 to 1910 m.a.s.l (Figure 1)

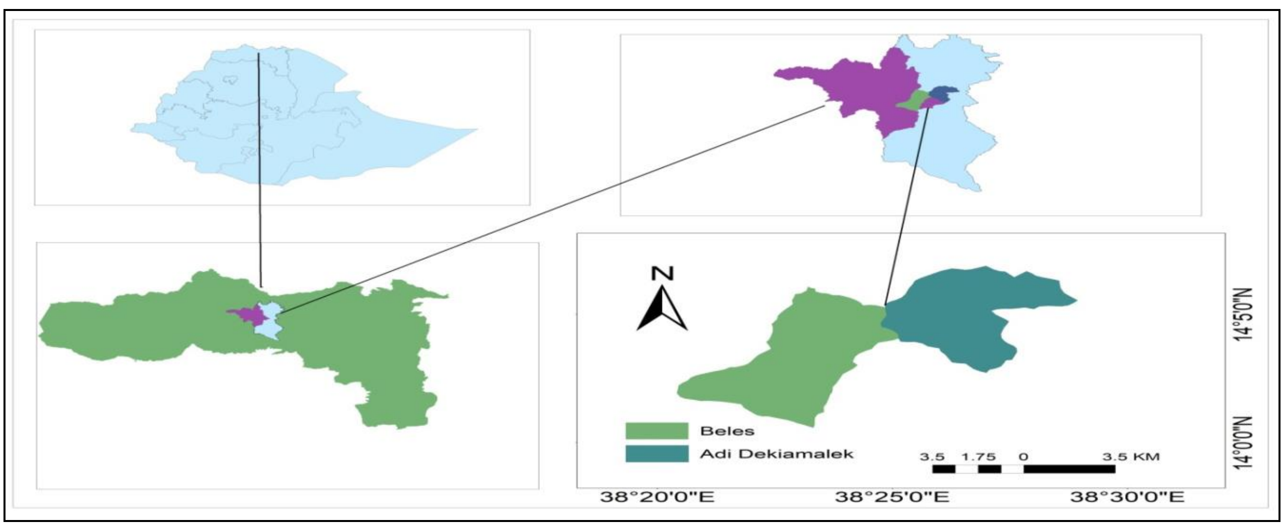

Figure 1. Location map of the study area at Medebay Zana and Tahtay Koraro, NW Tigray, Ethiopia

Climate data of the study area

The minimum and maximum monthly average temperatures of Medebay zana Woreda are 14.59 ^{0}C and 25.61 ^{0}C, respectively and the average rainfall is around 1002.25 mm. The minimum and maximum monthly average temperatures of Tahtay koraro are 10.23^{0}C and 28.06 ^{0}C, respectively and the average rainfall is around 1037.51 mm. These areas predominantly lie under semi-arid tropical belt of Ethiopia with a mono-modal and erratic rainfall pattern. The soil type of the study area is characterized as Vertisols. The WoredaWoredas are categorized under the semi-arid tropical mid highlands (SA_3) belt of Ethiopia with "W*einadega*" agro climatic zone where most of the middle altitude crops such as tef, sorghum, fababean, chickpea and others are commonly grown.

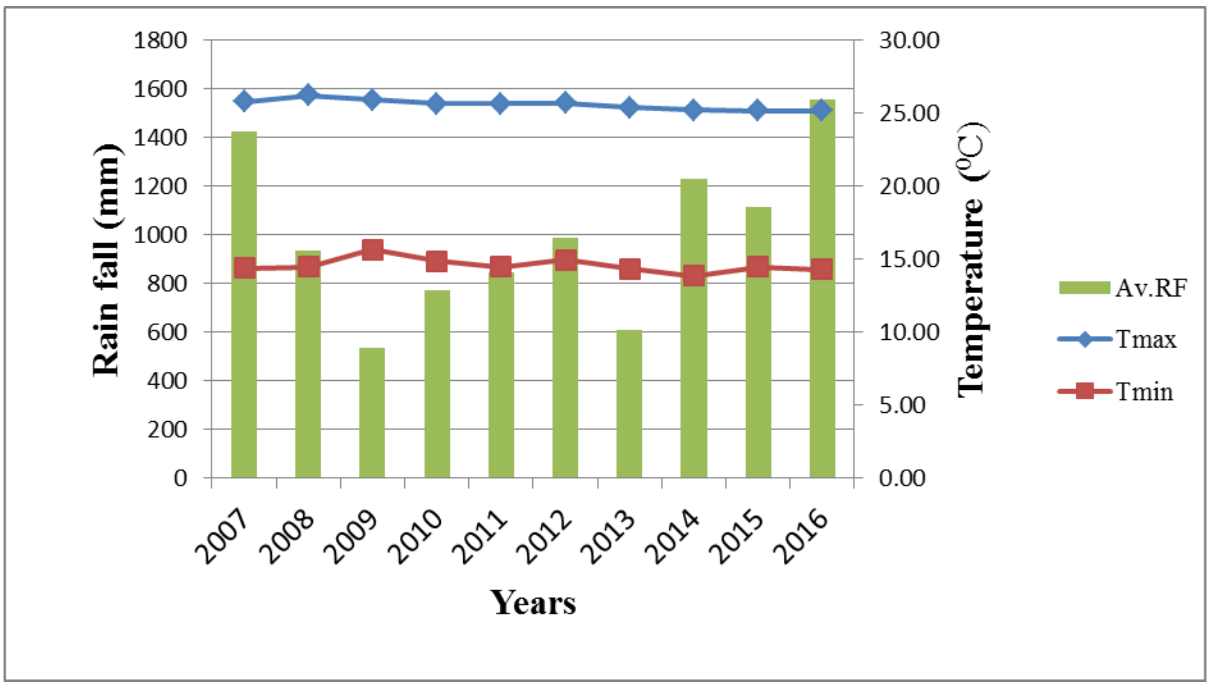

Figure **2.** Ten years' rainfall, maximum and minimum temperatures recorded for Medebay zana Woreda

Experimental design, treatment setup and procedures

The experiment was laid out in RCBD with eight treatments, seven levels of NPSZnB (0, 50, 100, 150, 200, 250, 300 kg NPSZnB ha^{-1}) and one rate of NP at 64 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1}. The plot size was 3 m by 3 m with three replications. The spacing between replication and plots were 1 m and 0.5 m, respectively. Since, N is the most limiting factor for plant growth and found in a very low amount in the blended fertilizer it was adjusted to the recommended level; so it was top dressed at two split (1/3 at 14 days after planting and 2/3 at 45 days after planting) while blended fertilizer was applied at sowing time. Tef was also planted in rows with 1m, 0.5m and 20 cm spacing between blocks, plots and row plants, respectively. Quncho variety was tested at seed rate of 5kg. All crop management practices were applied as per the recommendation for the tef crop.

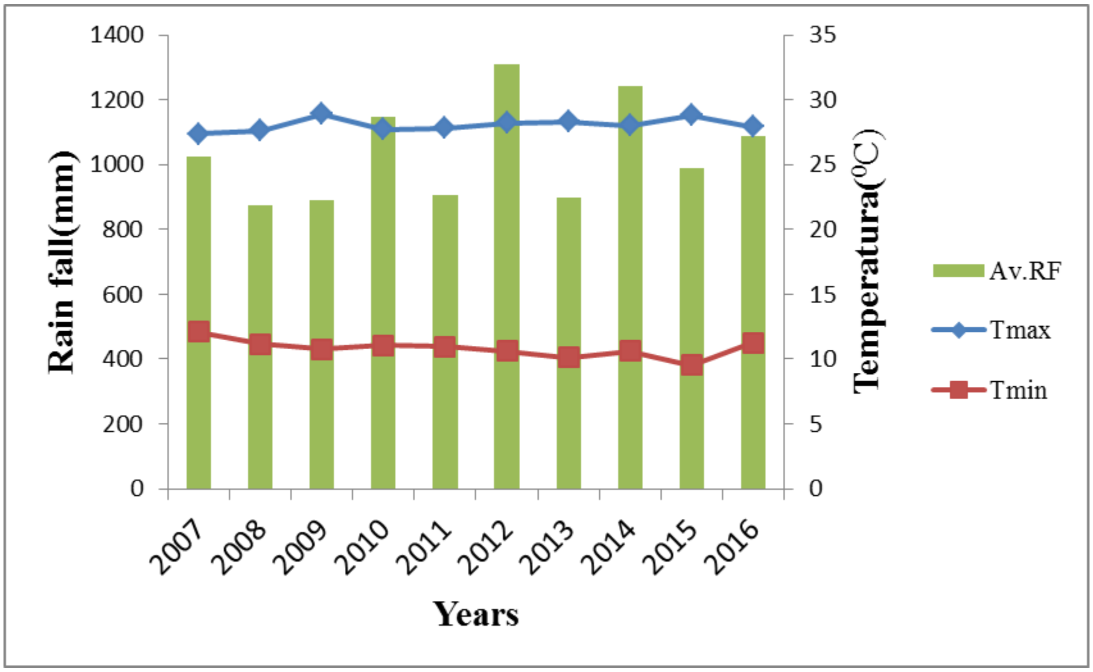

Figure 3**.** Ten years' rainfall, maximum and minimum temperatures recorded for Tahtay koraro Woreda

Soil data collection

Before planting one representative composite soil sample was taken 0 to 30 cm depth from each farmer's fields using an auger. The collected samples were properly labeled, packed and transported to Shire Soil Research Center. Particle size distribution was determined using the Bouyoucos hydrometer method (Bouyoucos 1962). The pH of the soil was measured in the supernatant suspension of a 1: 2.5 soil to water ratio using a pH meter (Rhoades 1982). Electrical conductivity (EC) (1:25 soil to water suspension) was measured according to the method described by Jakson (1967). Organic carbon (OC) was determined by the Walkely and Black (1934). Total N was determined using the Kjeldahl method as described by Bremner and Mulvaney (1982). Available P was determined following the Olsen method (Olsen et al 1954) using ascorbic acid as reducing agent.

Crop data collection

Agronomic data like days to heading, days to physical maturity, head length plant height, biomass yield, straw yield, grain yield and HI were collected following the standard procedures.

Data analysis

The collected data were subjected to statistical analysis. Analysis of variance (ANOVA) was carried out using Statistical Analysis System (SAS) statistical software program (SAS 2002). Treatment means were assessed using the least significant difference (LSD) at 0.05 level of probability (Gomez and Gomez 1984).

Partial budget analysis

To assess the costs and benefits associated with the different treatment rates, the partial budget technique of CIMMYT (International Center for Maize and Wheat Research) (1988) was applied to economic yield results. According to this manual, experimental yields are often higher than the yields that farmers could expect using the same treatments. Hence in economic calculations researchers have judged that farmers using the same technologies would obtain yields adjusted by 10% lower than those obtained by the researchers if the experiments are planted on representative farmers' fields, (CIMMYT 1988).

Result and Discussion

Soil characteristics of the study area

Particle size analysis, with sand (14-19%), silt (21-26%) and clay (58-62%) indicated that clay particles dominated the soil and its textural class was categorized as clay (Table 1). Vertisols are characterized by high clay content with swelling and shrinking characteristics. The soil pH of the study area ranged from 6.55-7.19 before sowing (Table 1) which was found to be slightly acidic to neutral soil.

Table 1. Physico- chemical soil characteristics of the study areas before sowing

Soil parameters	Year 1(2017)					Year 2 (2018)				
	Medebay zana Woreda		Tahtay koraro Woreda			Medebay zana Woreda		Tahtay koraro Woreda		
	Site 1	Site 2	Site 1	Site 2	Site 3	Site 1	Site 2	Site 1	Site 2	Site 3
pH(1:2.5)	7.19	6.55	6.71	6.59	7.19	6.85	6.91	6.89	6.99	6.86
EC (mmh/cm)	0.273	0.211	0.273	0.244	0.283	0.259	0.276	0.289	0.293	0.271
Av.P (ppm)	4.096	4.188	4.06	4.18	4.09	4.08	4.07	4.21	4.16	4.19
OM (%)	1.095	0.982	1.05	1.173	1.301	1.311	1.195	1.982	1.285	1.712
OC (%)	0.624	0.560	0.598	0.668	0.741	0.747	0.681	1.129	0.732	0.975
TN (%)	0.052	0.047	0.050	0.056	0.062	0.062	0.057	0.094	0.061	0.082
CEC(meq/100)	47.6	46.5	46	45.1	46.8	48.4	47.7	44.2	45.1	45
%sand	18	14	19	14	16	19	17	15	18	18
%silt	24	24	21	24	26	22	25	25	21	24
%clay	58	62	62	62	58	59	58	60	61	58
Tex. Class	clay	clay	clay	clay	clay	clay	clayey	clayey	clayey	clayey

pH= power of hydrogen, EC= electrical conductivity, OC= organic carbon, OM = organic matter, TN= total nitrogen, P_{av}= and CEC= cation exchange capacity

According to Landon (1991) soils having pH value in the range 5.5 to 7.5 are considered suitable for most agricultural crops. The EC was 0.211-0.293mmoh cm^{-1} before sowing indicating a non-saline soil (Marx et al., 1999). Generally, the EC value measured at the study area indicated the concentration of soluble salts are below the levels at which growth and productivity of most agricultural crops are affected due to soil salinity (Landon, 1991). Available P before sowing (4.06-4.21 ppm) was rated as very low (Olsen et al 1954). The OC and TN in soil before sowing was 0.56-1.129% and 0.047-0.082%, respectively (Table 1). According to Tekalign (1991), OC and TN levels of the study area were rated as low and very low, respectively. Low TN content of the soil could also be attributed to the low soil OC content. The C: N ratio of the study area was 7 and this was good for mineralization of nutrients available for plant growth. C: N ratio less than 25:1 goes through mineralization (Mohanty et al 2011). The CEC of the soil before sowing was 46-48.4 cmol (+) kg^{-1}. The soil CEC was found to be very high (Landon 1991). High CEC of the soil should be due to higher clay content of the soil as the soil OC content was found very low for the study site.

Growth parameters

Days to 50% heading and 90% physical maturity

The hastened panicle emergence as a result highest rates of NPSZnB could be due to early establishment, rapid growth and development of crop. The application of adjusted N hastened the days to heading possibly because the tef plants were able to take up sufficient N from the soil and also because uptake of N may have enhanced the uptake of other nutrients such as P and S which might speed up growth and development of the crop 90% physical maturity at Medebay zana Woreda. However, there was significant difference between the fertilized plots and the control plot, despite no statistical difference in between the plots treated with fertilizer at Tahtay koraro Woreda. The highest days to 90% physical maturity (107.22 days) was obtained for the control plots, while the lowest (102.39 days) was recorded for the blanket recommended NP (64 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1}) fertilizer (Table 2). The enhanced maturity with the application of blended fertilizer could be due to the presence of balanced fertilizer in the blended fertilizer, as the level of fertilizer increases physical maturity hastened.

Table 2. Days to 50% heading and days to 90% physiological maturity of tef as influenced by blended fertilizer (NPSZnB) rate

	Medebay zana		Tahtay koraro	
Treatments (kg ha^{-1})	DH (days)	DPM (days)	DH (days)	DPM (days)
Control (0,0)	62.67^{a}	110.17	63.06^{a}	107.22^{a}
50 NPSZnB	57.50^{b}	107.42	58.89^{b}	103.33^{b}
100 NPSZnB	56.08^{cb}	108.08	57.78^{b}	103.11^{b}
150 NPSZnB ^{1}	55.33^{cb}	107.92	56.89^{b}	103.00^{b}
200 NPSZnB kg ha^{-1}	54.50^{c}	107.00	56.83^{b}	102.94^{b}
250 NPSZnB kg ha^{-1}	55.25^{cb}	107.67	56.56^{b}	102.83^{b}
300 NPSZnB kg ha^{-1}	54.58^{c}	107.33	57.33^{b}	102.61^{b}
Rec.NP kg ha^{-1}	57.42^{b}	107.08	58.56^{b}	102.39^{b}
Mean	56.67	107.83	58.23	103.43
LSD($P \leq 0.05$)	2.69	NS	3.13	1.71
CV (%)	5.85	6.54	8.16	2.50

Where; DH= Days to 50% Heading, DPM= Days to 90% physiological maturity, LSD= Least Significant Difference, CV= Coefficient of Variance and NS = non significant; means followed by the same letters are not significantly different ($P \leq 0.05$) according to LSD Tests.

Plant height and head length

The analysis of variance showed no significant differences among the fertilized plots but they had significant differences ($P \leq 0.05$) with control plot in plant height in both WoredaWoredas. The highest plant height was 127.52 cm at Medebay zana and 119.3 cm at Tahtay koraro which were obtained from the highest NPSZnB kg ha^{-1} and 200kgha^{-1}, respectively, while the shortest plant heighst (113.52b cm and 78.86 cm) were recorded form the control plot in both Woredas (Table 3).

Whereas, panicle length showed no statistical difference at Medebay Zana Woreda. However, there were a significant difference between the fertilized plots and unfertilized plot at Tahtay koraro Woreda. Accordingly, the plots treated with 300 kg ha^{-1} NPSZnB had the highest panicle height (47.79 cm) but plots which received no fertilizer gave the lowest panicle length (Table 3). Similar to plant height, panicle length also increased with increasing N fertilizer rate.

Table 3. Plant height (cm) and panicle length (cm) of tef as influenced by blended fertilizer (NPSZnB) rate

TRT code	Treatments (kg ha^{-1})	Medebay zana		Tahtay koraro	
		PH (cm)	HL (cm)	PH (cm)	HL (cm)
	Control (0,0)	113.52^{b}	46.28	78.86^{b}	35.92^{b}
	50 NPSZnB	124.13^{a}	45.97	115.26^{a}	47.63^{a}
	100 NPSZnB kg ha^{-1}	124.93^{a}	47.58	118.06^{a}	47.42^{a}
	150 NPSZnB kg ha^{-1}	126.80^{a}	47.98	119.06^{a}	46.83^{a}
	200 NPSZnB kg ha^{-1}	128.92^{a}	48.10	119.30^{a}	47.52^{a}
	250 NPSZnB kg ha^{-1}	126.68^{a}	46.12	117.48^{a}	46.51^{a}
	300 NPSZnB kg ha^{-1}	127.52^{a}	47.13	118.21^{a}	47.79^{a}
	Rec.NP kg ha^{-1}	126.43^{a}	47.77	115.07^{a}	46.96^{a}
Mean		124.87	47.12	112.66	47.12
LSD($P \leq 0.05$)		5.90	NS	7.31	2.83
CV (%)		5.82	8.26	9.85	9.36

Where; PH= Plant height, PL= Panicle Length, LSD= Least Significant Difference and CV= Coefficient of Variance; means followed by the same letters are not significantly different ($P \leq 0.05$) according to LSD Tests.

Yield components and yield

Tillering capacity

The analysis of variance showed no significant difference on total tillering due to treatments at Medebay Zana Woreda but there were statistically significance difference between plots treated with fertilizer and control for Tahtay koraro Woreda. The highest number of total tillers (8.91 tillers) was obtained with the application of 50 kg NPSZnB ha^{-1} blended fertilizer, while the lowest number of total tillers (7.6 tillers) was obtained from the unfertilized plots (Table 4). The increased total tillers on plots treated with blended fertilizer than in the unfertilized plot might be due to the profound effect of balanced nutrition for root development and braches. This result is like that of Brhan (2012) who reported that application of blended fertilizer (69 kg N ha^{-1} + 46 kg P_2O_5 + 22 kg S ha^{-1} + 0.3 kg Zn ha^{-1}) brought significant increment in total tillers (15 tillers per plant) of tef as compared to unfertilized plot. Productive tillers were significantly affected ($P \leq 0.05$) by the treatments on both Woredas. The highest numbers of productive tillers (6.98 tillers at Medebay zana and 6.77 tillers at Tahtay Koraro) were obtained with the application of 300 and 150 kg NPSZnB ha^{-1} blended fertilizer, respectively, while the lowest number of productive tillers was obtained from the control plots (Table 4). The highest number of productive tillers might be due to sufficient amount of growth and development of plants owing to the essential elements under blended NPSZnB fertilizer condition.

In line with the results of this study, Fayera et al. (2014) found highest productive tillers of tef (26 tillers per plant) under the application of 200 kg ha^{-1} NPKSZnB (14 N, 21 P_2O_5, 15 K_2O, 6.5 S, 1.3 Zn and 0.5 B) + 23 kg N ha^{-1}).

Table 4. Tillering capacity per plant of tef as influenced by NPSZnB fertilizer rate

TRT code	Treatments (kg ha^{-1})	Medebay zana		Tahtay koraro	
		NT	NET	NT	NET
	Control (0,0)	9.42	5.75^{b}	7.60^{b}	4.37^{b}
	50 NPSZnB	8.75	6.05^{ba}	8.91^{a}	6.53^{a}
	100 NPSZnB kg ha^{-1}	9.67	6.97^{a}	8.60^{ba}	6.39^{a}
	150 NPSZnB kg ha^{-1}	9.48	6.63^{ba}	8.72^{ba}	6.77^{a}
	200 NPSZnB kg ha^{-1}	9.20	6.47^{ba}	7.92^{ba}	6.12^{a}
	250 NPSZnB kg ha^{-1}	9.15	6.63^{ba}	8.43^{ba}	6.61^{a}
	300 NPSZnB kg ha^{-1}	9.95	6.98^{a}	8.89^{a}	6.61^{a}
	Rec.NP kg ha^{-1}	9.63	6.50^{ba}	8.42^{ba}	6.24^{a}
Mean		9.41	6.50	9.41	6.21
LSD($P \leq 0.05$)		NS	1.01	1.26	0.97
CV (%)		20.31	19.16	22.71	23.66

Where; NT= Number of tillers per plot, NET= Number of effective tillers, LSD= Least significant difference and CV= Coefficient of Variance; means followed by the same letters are not significantly different ($P \leq 0.05$) according to LSD Tests

Straw yield

There was no statistically significant difference among fertilized plots at both Woredas. The highest straw yields (8422.0 kg ha^{-1} and 5880.9 kg ha^{-1}) were recorded from 300 and 250 kg ha^{-1} of NPSZnB in both Woredas, respectively. This result showed 36.3% and 67% straw yield increment over unfertilized plot and 12.1% and 15.9% over recommended NP for the two Woredas, respectively (Table 5). The plots treated with blended fertilizer scored higher straw yield due to combined effect of balanced fertilization. The highest plant height and tillers also had great contribution to higher straw yield. Fageria et al (2011) also indicated that application of S enhanced the photosynthetic assimilation of N in crops. Hence, application of N and S increased the net photosynthetic rate which in turn increased the dry matter as 90% of dry weight considered to be derived from products formed during photosynthesis.

The application of higher N fertilizer by adjusting to 64 kg ha^{-1} in the blended fertilizer also improved the straw yield by 36.3% and 67% over unfertilized plot (Table5). This might be due to its enhanced availability, uptake and induction of vigorous vegetative growth with more leaf area resulting in higher photosynthesis and assimilates that resulted in more dry matter accumulation (Brady and Weil, 2002).

Table 5. Biomass yield of tef (kg ha^{-1}), grain yield (kg ha^{-1}) and straw yield (kg ha^{-1}) of tef as influenced by blended fertilizer (NPSZnB) rate

Treatments (kg ha^{-1})	Medebay zana			Tahtay koraro		
	SY (kgha^{-1})	GY (kgha-1)	HI (%)	SY (kgha^{-1})	GY (kgha-1)	HI (%)
Control (0,0)	5362.0^{b}	1432.9^{b}	21.51^{a}	2530.7b	880.9^{b}	27.02
50 NPSZnB	7273.0^{ba}	1946.6^{ba}	21.14^{a}	5143.6a	1800.9^{a}	25.96
100 NPSZnB kg ha^{-1}	7104.0^{ba}	1870.6^{ba}	21.11^{a}	5497.4a	1838.8^{a}	24.85
150 NPSZnB kg ha^{-1}	7576.0^{a}	2039.4^{a}	21.27^{a}	5766.3a	1883.3^{a}	24.60
200 NPSZnB kg ha^{-1}	8187.0^{a}	2165.3^{a}	21.13^{a}	5733.3a	1795.2^{a}	24.34
250 NPSZnB kg ha^{-1}	7476.0^{a}	1946.9^{ba}	20.95^{a}	5880.9a	1996.6^{a}	25.37
300 NPSZnB kg ha^{-1}	8422.0^{a}	1952.2^{ba}	18.26^{b}	5602.0a	1876.6^{a}	25.40
Rec.NP kg ha^{-1}	7407.0^{a}	2005.3^{a}	21.52^{a}	4946.1a	1777.6^{a}	26.73
Mean	7350.93	1919.90	20.86	5137.53	1731.23	25.53
LSD($P \leq 0.05$)	2026.2	556.51	2.39	1090.3	371.71	NS
CV (%)	33.97	35.72	14.14	32.19	32.57	23.02

Where; Trt= treatment, BY= Biomass Yield, SY = Straw yield, Gy= Grain yield, HI= Harvest index, Variable means followed by the same letters are not significantly different ($P \leq 0.05$) according to LSD Tests.

Grain yield

The analysis of variance showed no significant difference among the fertilized plots but had significant differences with the control (unfertilized) plot at both Woredas. The highest grain yield (2165.3 kg ha^{-1}) was recorded as a result of 200 kg ha^{-1} NPSZnB. It had 56.9% yield increment over control and 7.4% over the blanket recommendation at Medebay zana Woreda (Table 5). Tahtay koraro Woreda also showed the same trend, the highest grain yield (1996.6 kg ha^{-1}) was recorded as a result of 250 kg ha^{-1} of NPSZnB (Table 5). It had 55.9% yield increment over control and 11% over the blanket recommendation.

Brhan (2012) reported that treatments that received blended fertilizers (69 kg N ha^{-1} + 46 kg P_2O_5 + 22 kg S ha^{-1} + 0.3 kg Zn ha^{-1}) under row planting of tef gave 4155 kg ha^{-1} and increased 30% and 378% over treatments that received urea and DAP under row planting and control plots, respectively. The highest grain yields (2165 and 1967 kg ha^{-1}) obtained in both Woredas in two consecutive research seasons was higher than the national average yield (1664 kg ha^{-1}) (CSA 2017).

Harvest index

Generally, HI indicates the balance between the productive parts of the plant and the reserves, which form the economic yield. High HI indicates the presence of good partitioning of biological yield to economical yield. The analysis of variance revealed no significant difference among any of the treatments in HI of tef except with control at medebay zana. However as the level of the fertilizer increased HI decreased. Therefore, the highest index was obtained at control plot (Table5). In line with this, Abraha (2013) and Tewolde (2018) reported the highest tef HI on lower rate of fertilizer application.

Partial budget analysis

As indicated in Table 5, the highest net benefit of 60628.38 Birr ha^{-1} with marginal rate of return (MRR) of 475.7% was obtained in response to application of 200 kg blended NPSZnB ha^{-1} (N was adjusted to 64 kg N ha^{-1}). However, the highest marginal rate of return (711%) was obtained in response to 50 kg ha^{-1}NPSZnB for Medebay zana Woreda. Similarly, at Tahtay koraro Woreda, the highest marginal rate of return (1173.3%) was obtained in response to 50 kg ha^{-1} NPSZnB. Thus, applications of 50 kg NPSZnB ha^{-1} with N adjusted to 64 kg N ha^{-1} is economical as compared to the other treatments in Medebay zana and Tahtay koraro Woredas.

Table 6. Economical analysis of the experiment

TRT	Adj. yield (10% less) (kg/ha)	Total Revenue (TR) [Grain yield*23.8] (1)	Adj. yield (10% less) (kg/ha)	Total Revenue (TR) [Grain yield*3.1] (2)	Gross Revenue Sum (1+2)	fertilizer cost [Birr]	Transport and Application cost [Birr]	Total variable cost (TVC) [Birr]	Net Revenue [TR-TVC]	MRR (ratio) [(Rt2-Rt1)/(Ct2-Ct1)]	MRR (%)
Medebay zana Woreda											
Control (0,0)	1289.61	30692.72	4825.8	5159.6	35852.32	0	0	0	35852.32	0.000	0.0
50NPSZnB	1751.94	41696.17	6545.7	11351.6	53047.77	1980.25	140	2120.25	50927.52	7.110	711.0
100NPSZnB	1683.54	40068.25	6393.6	16402.4	56470.65	2708.85	210	2918.85	53551.8	3.286	328.6
Rec.NP(100:100)	1804.77	42953.53	6666.3	11995.1	54948.63	2918.75	210	3128.75	51819.88	D	D
150NPSZnB	1835.46	43683.95	6818.4	16862.8	60546.75	3437.45	280	3717.45	56829.3	4.104	410.4
200NPSZnB	1948.77	46380.73	7368.3	18763.7	65144.43	4166.05	350	4516.05	60628.38	4.757	475.7
250NPSZnB	1752.21	41702.6	6728.4	21288.6	62991.2	4894.65	420	5314.65	57676.55	D	D
300NPSZnB	1756.98	41816.12	7579.8	21855.9	63672.02	5623.25	490	6113.25	57558.77	D	D
Tahtay koraro Woreda											
Control (0,0)	792.81	18868.88	2277.63	7060.65	25929.53	0	0	0	25929.5	0	0.0
50NPSZnB	1620.81	38575.28	4629.24	14350.6	52925.92	1980.25	140	2120.25	50805.7	11.73	1173.3
100NPSZnB	1654.92	39387.1	4947.66	15337.7	54724.84	2708.85	210	2918.85	51806	1.25	125.3
Rec.NP(100:100)	1599.84	38076.19	4451.49	13799.6	51875.81	2918.75	210	3128.75	48747.1	D	D
150NPSZnB	1694.97	40340.29	5189.67	16088	56428.26	3437.45	280	3717.45	52710.8	1.13	113.3
200NPSZnB	1615.68	38453.18	5159.97	15995.9	54449.09	4166.05	350	4516.05	49933	D	D
250NPSZnB	1796.94	42767.17	5292.81	16407.7	59174.88	4894.65	420	5314.65	53860.2	0.72	72.0
300NPSZnB	1688.94	40196.77	5041.8	15629.6	55826.35	5623.25	490	6113.25	49713.1	D	D

NB: GY= grain yield, AY= adjusted yield, TR= total revenue, SY= straw yield, GR= gross revenue, FC= fertilizer cost, TaAC= total and application cost' NR= net revenue and MRR= marginal rate of return

Conclusion and Recommendation

The study revealed the potential advantages of blended fertilizer rates (NPSZnB) over the N P blanket recommendation for tef production grown on Vertisols in two year experimentation on both Woredas. From this study, it was possible to conclude days to 50% heading, plant height, number of productive tillers per plant, straw yield, grain yield and HI resulted in significant differences over the control plot at Medebay zana Woreda.Similarly, days to 50% heading, days to 90% physical maturity, plant height, panicle length, total tillers per plant, number of productive tillers per plant, straw yield and grain yield showed significant difference over the control plot at Tahtay koraro Woreda (Beles kebelle). However, days to 90% physical maturity and head length (panicle length) at Medebay zana Woreda and HI at Tahtay koraro had no significant difference with in any of the treatments. Both biological and partial budget analysis revealed that 50 kg ^{1} NPSZnB ha^{-1} with 55.25 kg N ha^{-1} (120 kg/ha urea) can be recommended for Medebay zana and Tahatay koraro areas for tef production.

Acknowledgements

The authors are grateful to Tigray Agricultural Research Institute (TARI) and Agricultural Growth Program (AGP) II project for their providing financial support and for their warm assistance during the implementation of this work in producing this piece of output.

References

Abraha Arefaine. (2013): Effects of rates and time of nitrogen fertilizer application on yield and yield components of Ttef [Eragrostis tef (Zucc.) Trotter] in Habro Woreda, Eastern Ethiopia. M.Sc. Thesis, Haramaya University, Haramaya, Ethiopia.

Akram A Mussarrat F Safdar A Ghulam J and Rehana A (2007): Growth, yield and nutrients uptake of sorghum in response to integrated phosphorus and potassium management: Pak. J. Bot., 39(4): 1083-1087.

Alloway BJ (2008): Zinc in soils and crop nutrition: International fertilizer Industry Association. Sec. ed. IZA and IFA Brussels, Belgium and Paris, France.

Asgelil Debebe Taye Bekele and Yesuf Assen. (2007):The status of Micro-nutrients in Nitisols, Vertisols, Cambisols and Fluvisols in major maize, wheat, tef and citrus growing areas of Ethiopia. In: Proceedings of Agricultural Research Fund Research Projects Completion Workshop held on 1-2 February 2007 at Ethiopian Institute of Agricultural Research, pp 77-96.

ATA (Agricultural Transformation Agency) (2013a): Transforming the use of fertilizer in Ethiopia: Launching the national fertilizer blending program; February 12, 2013.

ATA (Agricultural Transformation Agency) (2013b): "Working Strategy for Strengthening Ethiopian's Tef Value Chain Vision, Systemic Challenges, and Prioritized Interventions". Addis Ababa, Ethiopia.

ATA (Agricultural Transformation Agency) (2014): Soil Fertility Status and Fertilizer Recommendation Atlas for Tigray Regional State; Ethiopia July 2014.

Bekabil Fufa and Hassan Rashid, (2006): Determinants of fertilizer use on maize in eastern Ethiopia: A weighted endogenous sampling analysis of the extent and intensity of adoption, 45(1): 38-49.

Berhanu Debele (1985): The Vertisols of Ethiopia-Their properties, classification and management. 5th Meeting of the Eastern African Soil Correlation and Land Evaluation Sub-Committee, 4-10 December 1983, Wad Medani Sudan. World Soil Resources Report 56. FAO (Food and Agriculture Organization of the United Nations), Rome. 31-54pp.

Bouyoucos J (1962): Hydrometer method improved for making particle size analysis of soil. *Agronomy Journals* (54):464-465.

Brady NC and Weil RR (2002): The Nature and Properties of Soils.13th edition. Pearson Education Ltd, USA.

Bremner JM and Mulvaney CS (1982): Nitrogen - Total. In A.L. Page, R.H. Miller and D.R.Keeney (eds.). Methods of soil analysis. Part 2-Chemical and microbiological properties. Agronomy, 9 (2): 595-624. *American Society of Agronomy*. Madison, Wis.

Brhan Abayu (2012): Agronomic and economic effects of blended fertilizers under planting method on yield and yield components of tef. M.Sc. Thesis, Mekelle University, Mekelle, Ethiopia.

CIMMYT (International Center for Maize and Wheat Research) (1988): From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely Revised Edition, Mexico, DF.79 pp.

CSA (Central Statistical Agency) (2016): Agricultural sample survey for the 2015/2016 crop season. Volume II Report on area and production of crops for private peasant holdings (Meher season) Statistical Bulletin 446. FDRE/CSA, Addis Ababa, Ethiopia.

CSA (Central Statistics Agency) (2017): The Federal Democratic Republic of Ethiopia, agricultural sample survey 2016/2017 (2009 E.C.) Vol. I. Report on area and production of major crops (Private peasant holdings ''Meher'' season), Statistical Bulletin 584, Addis Ababa, Ethiopia.

Fageria NK, Baligar VC and Jones C A (2011): Growth and mineral nutrition of field crops.3rdEdn., Taylor &Francis Group, New York, 530 p.

FAO (Food and Agriculture Organization of the United Nations) 2014: Guidelines for soil description. 5th edition. Rome.

Gibbson RS (2006): Zinc: the missing link in combating micronutrient malnutrition in developing countries. Proceedings of the Nutrition Society, University of East Anglia, Norwich, June 28 - July 1, 2005.

Gomez and Gomez H (1984): Statistical analysis for agricultural research. John Willy and Sons Inc. pp.120-155.

Jackson ML (1967): Soil chemical analysis. Practice Hall of India. New Delhi.

Landon JR (1991): Booker Tropical Soil Manual: A hand book for soil survey and agricultural land evaluation in the tropics and subtropics. Longman Scientific and Technical, Essex, New York. 474p. OR John Wiley & Sons Inc., New York

Malakouti MJ (2008): The effect of micronutrients in ensuring efficient use of macronutrients: Soil Science Department; Tarbiat Modares University. Turk J. Agric (32) 215-220.

MoA (Ministry of Agriculture) and ATA (Agricultural Transformation Agency) (2014): Soil fertility and fertilizer recommendation atlas for Tigray regional state, Addis Ababa. Ethiopia.

Mohantty M Reddy SK Probert ME Dalal, RC, Rao, SA. and Menzies NW (2011): Modelling nitrogen mineralization from green manure and farmyard manure from a laboratory incubation study. Ecol.Model. 222, 719-726

Olsen R Cole S Watanabe F and Dean L (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. United States Department of Agriculture Circ. 939.

Rhoades JD (1982): In methods of soil analysis, Part 2. Second Edition (A.L. Page. Miller and D.R. Keeney, Eds.), American Society of Agronomy. Madison, USA.

SAS (Statistical Analysis Software) 2002: SAS/STAT User's Guide, Version 9.1.3. SAS institute Inc., Cary, NC.

Tarekegne Berhe (2010). Breeding and genetic resources of tef (Eragrostis tef) in Ethiopia. Institute of Agricultural Research, Addis Ababa, Ethiopia.

Tekalign Tadese (1991): Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document. No. 13. International Livestock Research Center for Africa, Addis Ababa.

Walkley A and Black IA (1934): An examination of the Degtjareff method for determining soil organic matter and proposed chromic acid titration method. Soil Science, (37):29-38

Evaluation of NPSB Blended Fertilizer on Quality, Yield, and Yield Components of Tef under Rain-Fed Condition in Laelay Maichew, Tigray

Tsadik Tadele*, Geberesemaeti Kahsu, Weldegebrel Gebrehiwet, Tewolde Berhe, Kinfe Tekulu, Tarekegn Yibabie, Solomon Mebrahtom, Samrawit Mebrahtu

[1,] Tigray Agricultural Research Institute, Shire Soil Research Centre, P.O. Box 40, Shire, Ethiopia;

*Correspondence: tsadiktadele27@yahoo.com

Abstract

Nitrogen (N) and phosphorus (P) were identified as being the most deficient nutrients in almost all soils including in Laelay Maichew four decades ago, and application of fertilizers containing N and P (urea and di-ammonium phosphate (DAP)] began in the late 1960s. In addition to N and P deficiencies, two soil nutrients [sulfur (S) and boron (B)] are found to be deficient in the soils. As a result NPSB blended fertilizer type was formulated by EthioSIS, to improve sustainable tef production. However the rate of the formulated blended fertilizer for yield and yield components of tef was not yet determined. Hence, a field experiment was conducted to evaluate NPSB fertilizer rates on quality, yield and yield components of tef on the study site during 2017/2018 main cropping season at Beles Tabia in Laelay Maichew Woreda of Tigray Regional State. Eight treatment combinations (0, 50, 100, 150, 200, 250, 300 kg NPSB ha^{-1} and blanket Recommended NP at the rate of 64 kg N ha^{-1}and 46 kg P_2O_5 ha^{-1}) were tested. The experimental design was randomized complete block (RCBD) with three replications. The treatments significantly affected crop phenology, yield and yield components of tef as compared to control. Highest mean tef grain yield (2359.1 kg ha^{-1} kg ha^{-1}) was obtained in response to the application of 150 kg ha^{-1} of NPSB blended fertilizer.. It had 46.9% yield increment over control and 6.4% over the blanket recommendation. The highest (9900.3 kg ha^{-1}) above ground dry biomass and straw (7554.6 kg ha^{-1}) yield were recorded from 200 kg ha^{-1} of NPSB. Both biological and partial budget analysis showed that 50 kg ha^{-1} NPSB with 55.25 kg N ha^{-1} (120 kg urea) was economically profitable and is recommended for farmers in Laelay maichew Woreda and other areas with similar soil and agro-ecological conditions.

Key words: Blended fertilizers, tef, marginal rate of return, laelay maichew

Introduction

Declining soil fertility, poor management practices and shortage of rainfall are among the major causes of low productivity of crops in Ethiopia. In order to alleviate these problems in Ethiopia, one of the measures to be taken is to improve the soil fertility status of the soil and to use the right seed rate. Since the soils of Tigray are among the highly degraded soils, adoption of improved agronomic practices is vital to increase productivity of the soil [Ethiopian Soil Information System (EthioSIS), 2015].

Land degradation, especially soil erosion, nutrient depletion, and soil moisture stress are severe problems in the highlands of Tigray. Land management is therefore a key problem area in addressing land degradation in the region. The proximate causes of land degradation are relatively well known. These factors include cultivation of steep slopes and erodible soils, low vegetation cover of the soil, burning of dung and crop residues, declining fallow periods, low and uncertain rainfall, and limited application of organic or inorganic fertilizers. Little is known, however, of the underlying causes of land degradation, which are thought to include population pressure, poverty, high cost or limited access of farmers to fertilizer, fuel and animal feed, limited farmer knowledge of integrated soil and water management measures, lack of access to credit, and other factors (Berhanu, 2002).

One of the methods to improve the crop production and soil fertility is to use mineral fertilizers. It has been estimated that at least 30 to 50% of crop yield increment is attributable to application of commercial fertilizers (Stewart *et al.,* 2005). In Tigray, fertilizer application is mostly done based on blanket recommendations which does not consider the soil fertility status of the location. By doing so we are either applying less than the requirement of the crop or applying more which is not optimal for better yield. It is true that when a soil fails to supply sufficient essential nutrients for normal plant growth, applications of supplemental nutrients are required [Food and Agriculture Organization of the United Nations (FAO), 2008]. Nitrogen and P were identified as being the most deficient nutrients in almost all Ethiopian soils four decades ago, and application of fertilizers containing N and P (urea and di-ammonium phosphate (DAP)] began in the late 1960s (Wassie and Tekalign, 2013) to improve the productivity of the soil. The blanket recommendation [(100 kg DAP (18-46-0) and 100 kg urea (46-0-0)] often fails to take into consideration differences in resource endowment (soil type, labor capacity, climate risk) or make allowances for dramatic changes in input/output price ratio, thereby discouraging farmers from fertilizer application. Moreover, the nutrients in the blanket recommendation are not well balanced agronomical and its continued use will gradually exhaust soil nutrient reserves [Agricultural Transformation Agency (ATA), 2013]. Therefore, neither yields nor profits can be sustained using imbalanced application of fertilizers.

In Tigray region, the productivity of soils reduced and consequently led to the decline in agricultural productivity (Engdawork, 2002).In the region, seven soil nutrients [N, P, potassium

(K), sulfur (S), iron (Fe), zinc (Zn) and boron (B)] are found to be deficient in the soils (EthioSIS, 2015). By considering the extent of deficiency of the 7 soil nutrients, it was found that Tigray soils require more fertilizer types. However, with the prevailing resource limitations to prepare and distribute these many fertilizers (most of them for few number of farmers), it was deemed necessary to prioritize the types of new fertilizers to use in the region without compromising the nutrient requirement of the particular areas. By so doing, Tabia based site specific 11 types of blended fertilizers are recommended for agricultural land in the region [Ministry of Agriculture (MoA) and ATA, 2014]. Laelay Maichew Woreda is one of the woredas in Tigray weredas which were included in the EthioSIS fertilizer recommendation. Different blended fertilizers types were identified for each kebelle. According to nutrient deficiency level of the kebelle soil one up to three blended fertilizers, 1st (70-100%), 2nd (20-30%) and 3rd below 20% were identified for one kebelle. Accordingly Hatsebo kebelle soil has N, P, S and B nutrients deficiency; as a result the NPSB blended fertilizer type is recommended to improve sustainable soil production of the kebelle (EthioSIS, 2014). Following the recommendation, very few studies like that of (Brhanu, 2012) who did his thesis research at Laelay Maichew Woreda, stated that the different blended fertilizers have significant difference over the blanket recommendation although the rate of the fertilizers is still undetermined. Therefore, this study was conducted to evaluate NPSB fertilizer rate on quality, yield and yield component of tef on the study site.

Materials and Methods

Description of the study area

The study was conducted at Hatsebo Tabia, Laelay Maichew woreda, Central zone of Tigray, northern Ethiopia. The experimental sites (Figure1) are found at 14^0 05' 29.22" N and 38^0 46' 48.67" E with an elevation of 2078 m.a.s.l. to 14^{0}06’23.415’’N, 38046’28.542’’E and altitude of 2091masl. The Woreda is found in a semi-arid tropical mid highlands (SA_3) belt of Ethiopia with “W*einadega*” agro-climatic zone. The farming system of Hatsebo Tabia is mixed crop-livestock production system. The major crops grown in the area include tef, wheat, faba bean, sorghum, and chickpea. It is one of the major tef growing areas in Tigray. It has a total area of 3283.3 hectare. Out of the total area, 2341 ha is a rain fed arable land, 68 ha is used for irrigation, 726 ha is conserved as a forest area, 50 ha for grazing land, and 89.5 is out of use for agriculture. There are an estimated 11,428 livestock population and 298 bee hives in the Tabia [Central Statistical Agency (CSA), 2016)]

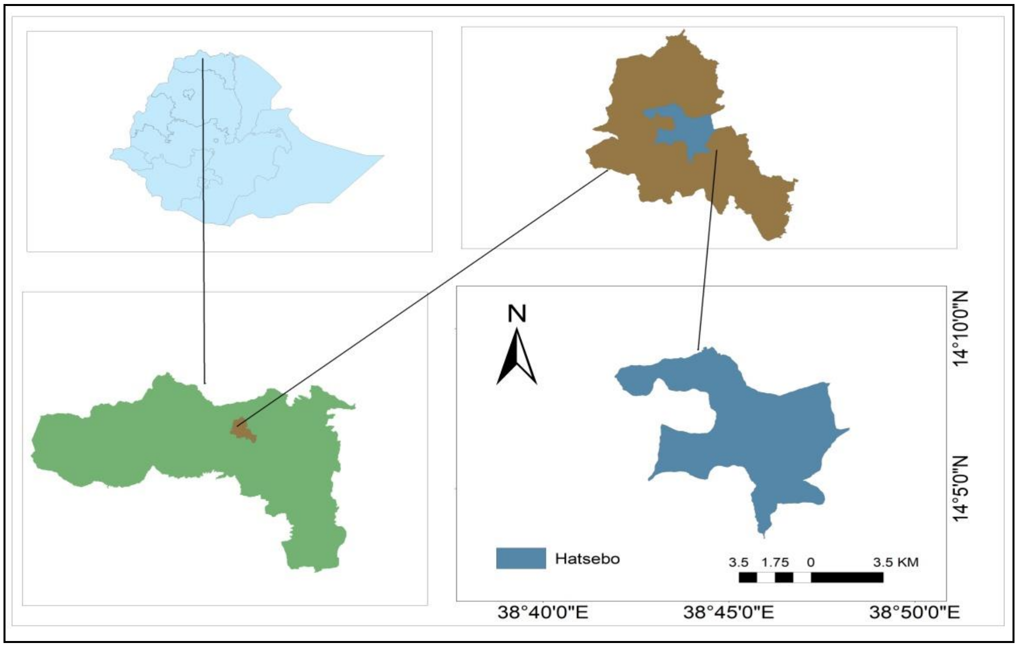

Figure 1. Location map of the study area at Laelay Maichew, Centray Tigray, Ethiopia

Climatic condition of the study area

The mean annual rainfall ranges from 750 to 937 mm with uni-modal rainfall pattern (Meteorological Agency, 2018). The main rainy season with high rainfall intensity, which is locally called *kiremi* extends from July to September. The mean annual temperature of the area is between 13.2^{o}C and 28.5^{o}C, (WoARD, 2018).The study area obtained rainfall of 814.3 mm during the cropping season (January-December, 2017/2018) (Figure 2). Mean maximum and minimum temperatures during the cropping season were 13.5 and 27.5 in 2017 and 13.2^{o}C and 28.4^{o}C, in 2018 respectively (Figures 2 and 3).

Treatment and experimental design

Field experiments were conducted for two consecutive seasons (2017 and 2018) under rain fall conditions on six selected farmer's fields at Hatsebo Tabia, Laelay maichew WoredaWoredas of central Tigray, northern Ethiopia. The soil textural clss of the study area was characterized as vertic clay soil (Tewolde, 2018).

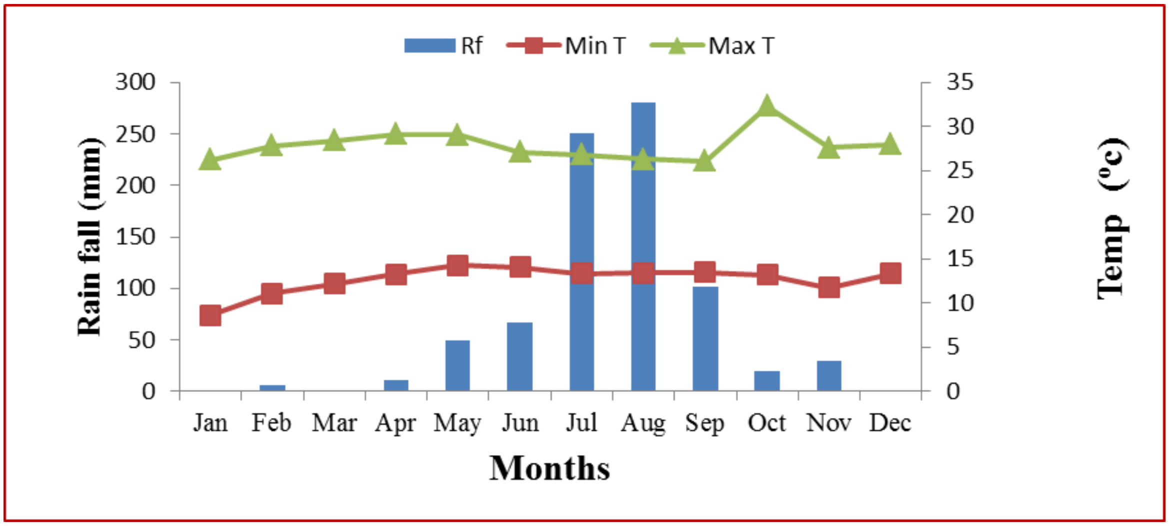

Figure 24. Rainfall, maximum and minimum temperatures recorded in the study area during the cropping season

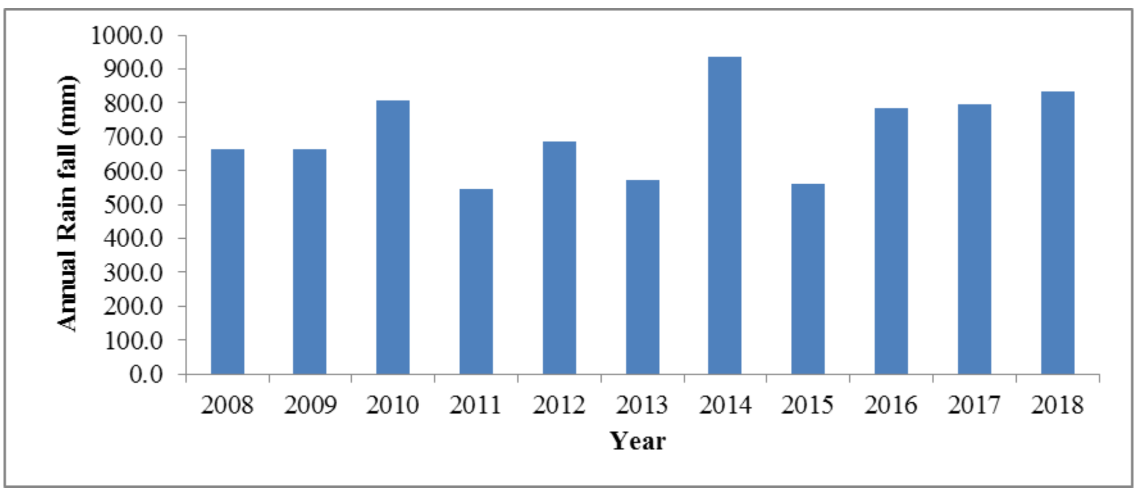

Figure 3. Ten years annual rainfall recorded in the study area

The type of blended fertilizer (NPSB) was selected based on soil fertility atlas of Ethiosis (2014). Based on the soil information data of Ethiosis (2014), eight treatments (0, 50, 100, 150, 200, 250, 300 kg NPSB ha^{-1} and blanket Recommended NP at rate of 64 kg N $ha^{-1}$and 46 kg P_2O_5 ha^{-1}) were formulated and tested. The seven blended (NPSB) fertilizer rates were compared to each other and with the blanket recommended NP fertilizer to determine one best fitted rate. Since, nitrogen is the most limiting factor for plant growth and found in a very low amount in the blended fertilizer, it was adjusted to the recommended level; so it was top dressed at two split.

Blended fertilizers were applied at sowing time but nitrogen fertilizer was applied half at vegetative stage while the rest was at flowering stage. The test crop was also planted in rows with 1m, 0.5m and 20 cm spacing between blocks, double rows and row plants, respectively. All crop management practices were applied as per the recommendation for tef. The treatments were laid out in RCBD with three replications. Plot size of the trial was 3 m by 3 m for tef planted in rows, replicated 3 times on site and across three farmers' fields of each year.

Soil data collection

Before planting one representative composite soil sample was taken at 0 to 30 cm depth from each farmer's fields using an auger. The collected samples were properly labeled, packed and transported to Shire soil research center. Particle size distribution was determined using the Bouyoucos hydrometer method (Bouyoucos 1962). The pH of the soil was measured in the supernatant suspension at 1: 2.5 soil to water ratio using a pH meter (Rhoades 1982). Electrical conductivity (EC) (1:25 soil to water suspension) was measured according to the method described by Jakson (1967). Organic carbon (OC) was determined by the Walkely and Black (1934). Total N was determined using the Kjeldahl method as described by Bremner and Mulvaney (1982). Available P was determined following the Olsen method (Olsen et al 1954) using ascorbic acid as reducing agent.

Crop data collection

Agronomic data such as days to heading, days to physical maturity, head length plant height, straw yield, grain yield and harvest index were collected.

Data analysis

The collected data were subjected to statistical analysis. Analysis of variance (ANOVA) was carried out using Statistical Analysis System (SAS) statistical software program (SAS 2004). Significant difference between and among treatment means were assessed using the least significant difference (LSD) at 0.05 level of probability (Gomez and Gomez 1984).

Physico-Chemical properties of the soil samples before planting

Table 1. Pre sowing selected soil physic-chemical property of surface soil samples (0-20cm) collected from the experimental sites

Soil Property	Year1		Year 2			
	Site 1	Site 2	Site 1	Site 2	Site 3	Site 4
pH (H_2O)	6.5	6.98	7	6.4	6.61	7.38
EC (ds/m)	0.262	0.405	0.521	0.251	0.453	0.661
Av. P (PPm)	4.659	4.980	6.345	5.235	9.960	19.526
% OC	0.589	0.669	0.680	0.578	0.639	1.064
% TN	0.051	0.058	0.059	0.049	0.055	0.091
CEC (meq per /100g soil)	37.00	39.00	37.60	37.00	38.80	34.2
% Sand	16	24	18	20	15	15
% Silt	35	33	35	32	30	35
% Clay	49	43	47	48	45	50
Textural Class	Clay	clay	clay	clay	clay	clay

Economic Analysis

To assess the costs and benefits associated with the different treatment rates, the partial budget technique of International Center for Maize and Wheat Research (CIMMYT) (1988) was applied to economic yield results. According to this manual, experimental yields are often higher than the yields that farmers could expect using the same treatments; hence in economic calculations researchers have judged that farmers using the same technologies would obtain yields adjusted by 10% lower than those obtained by the researchers if the experiments are planted on representative farmers' fields, (CIMMYT, 1988).

Result and Discussion

Days to 50% heading and days to 90% maturity

Application of different levels of NPSB fertilizer have not statically affected 90% physiological maturity where as in days to 50% heading there was significant difference among the treatments. Thus, plots that received higher rates of blended fertilizers headed earlier than control plots. Comparing days to heading treatment 1 (control) had the highest days to heading which is 72.72 days. Even though there were no significance differences among plots treated with blended fertilizer treatment 6 (250 kg/ha) had the lowest number of days to heading. Similar to this findings, Tesfahun, (2018) reported that application of NPS fertilizer hastened the number of days required to heading compared to that of control. Generally as the rate of NPS increased, the number of days elapsed to heading was shortened.

Table 2. Days to 50% heading and days to 90% physiological maturity of tef as influenced by Blended fertilizer (NPSB) rate

Treatments kg ha^{-1}	DH (days)	DPM (days)
Control (0,0)	72.72a	109.22
50 NPSB	66.00b	105.67
100 NPSB [1]	63.78b	105.22
150 NPSB	62.78b	105.33
200 NPSB	61.83b	105.22
250 NPSB	61.06b	105.00
300 NPSB	61.44b	105.22
Rec.NP	64.89b	105.28
Mean	64.31	105.77
LSD(P≤0.05)	6.18	NS
CV (%)	14.58	10.56

Where; DH= Days to 50% Heading, DPM= Days to 90% physiological maturity, LSD= Least Significant Difference, CV= Coefficient of Variance and NS = non significant; means followed by the same letters are not significantly different (P ≤ 0.05) according to LSD Tests.

Plant height and head length of tef

The analysis of variance showed no significant differences among the treatments received blended fertilizer rates but they have significant difference ($P \leq 0.05$) with control plot both in plant height and panicle length. Accordingly, the plot treated with 200 kg ha^{-1} NPSB had the highest plant height (130.52cm) and panicle length (48.76cm) but the control plot which were received no fertilizer gave the lowest plant height and panicle length (Table 2). According to Feyera et al (2014), application of balanced fertilizer and efficient utilization of nutrient leads to high photosynthetic productivity and accretion of dry matter, eventually increased panicle length.

Table 3. Plant height (cm) and panicle length (cm) of tef as influenced by blended fertilizer (NPSB) rate

Treatments kg ha^{-1}	PH(cm)	PL(cm)
Control (0,0)	89.24b	36.71b
50 NPSB	126.27a	47.60a
100 NPSB	125.29a	46.34a
150 NPSB	129.60a	48.20a
200 NPSB	130.52a	48.76a
250 NPSB	126.99a	46.20a
300 NPSB	128.90a	48.58a
Rec.NP kg	121.40a	47.68a
Mean	122.28	46.26
LSD(P≤0.05)	9.45	4.68
CV (%)	11.72	15.36

Where; PH= Plant height, PL= Panicle Length, LSD= Least Significant Difference and CV= Coefficient of Variance; means followed by the same letters are not significantly different (P ≤ 0.05) according to LSD Tests.

Tillering capacity of Tef

The analysis of variance showed no significant differences on total tillering but there were significant difference ($P \leq 0.05$) in the plots with fertilizer and control plot on productive tillering. Higher (10.39) number of total tillers per plant was obtained from plot supplied with 150 kg ha^{-1} and the minimum (9.57 per plant) was observed from unfertilized control plot (Table 3). On the other hand, maximum (8.06) number of effective tillers per plant was recorded at the rate of 150 kg ha^{-1}, while the minimum (6.06) number of tillers was observed under unfertilized plot. The highest fertile tiller was obtained at the rate of 90 kg ha^{-1} (15.55) and 120 (15.17) kg ha-1NPS wherein statistical parity and the lowest number of fertile tiller (11.5) was recorded at zero application rate (Tesfahun, (2018).

Table 4. Numbers of tillers and effective tillers per plot of tef as influenced by blended fertilizer (NPSB) rate

Treatments kg ha^{-1}	NT	NET
Control (0,0)	9.57	4.7556b
50 NPSB	10.10	7.17a
100 NPSB kg ha^{-1}	9.81	7.01a
150 NPSB kg ha^{-1}	10.39	8.06a
200 NPSB kg ha^{-1}	9.14	6.8a
250 NPSB kg ha^{-1}	9.79	6.9a
300 NPSB kg ha^{-1}	9.71	7.12a
Rec.NP kg ha^{-1}	9.62	6.9a
Mean	9.77	6.84
LSD($P \leq 0.05$)	NS	1.34
CV (%)	26.55	29.77

Where; NT= Number of tillers per plot, NET= Number of effective tillers, LSD= Least significant difference and CV= Coefficient of Variance; means followed by the same letters are not significantly different ($P \leq 0.05$) according to LSD Tests.

Straw yield of Tef as influenced by blended fertilizers

Above ground dry biomass and straw yield were highly significantly ($P \leq 0.05$) influenced by the blended fertilizers rates. The highest straw yield (7554.6 kg ha^{-1}) was recorded from 200 kg ha^{-1} of NPSB which showed that the blend fertilizer contributed to enhance the aboveground dry biomass and straw yield of tef. This result showed 60.4% straw yield increment over unfertilized plot and 19.2% increment over recommended NP (Table 4). Biological yield is a function of photosynthetic rate and proportion of the assimilatory surface area. Hence, the increase in straw yield with increase in rate of blended fertilizer might be due to N and S integrated effect which caused better for vegetative growth of crops and ultimately produced more biological yield.

Table 5. Grain yield (kg ha^{-1}) and Straw yield (kg ha^{-1}) of tef as influenced by blended fertilizer (NPSB) rate

Treatments kg ha^{-1}	SY (kg ha^{-1})	GY (kg ha^{-1})	HI (%)
Control (0,0)	2991.9^{c}	1253.1^{b}	32.19^{a}
50 NPSB	6281.6^{ba}	2301.0^{a}	27.55^{b}
100 NPSB kg ha^{-1}	6593.8^{ba}	2309.3^{a}	26.65^{b}
150 NPSB kg ha^{-1}	7170.8^{ba}	2359.1^{a}	25.73^{b}
200 NPSB kg ha^{-1}	7554.6^{a}	2345.7^{a}	24.68^{b}
250 NPSB kg ha^{-1}	7346.4^{ba}	2176.4^{a}	23.86^{b}
300 NPSB kg ha^{-1}	7176.7^{ba}	2232.1^{a}	25.09^{b}
Rec.NP	6104.3^{b}	2207.7^{a}	27.79^{b}
Mean	6402.52	2148.05	26.69
LSD($P \leq 0.05$)	1276.4	205.59	4.03
CV (%)	30.24	14.52	22.88

Where; Trt= treatment, SY = Straw yield, Gy= Grain yield, HI= Harvest index,, Variable means followed by the same letters are not significantly different ($P \leq 0.05$) according to LSD Tests.

The result was in conformity with the finding by Adera Sisay (2016) who reported that above ground dry biomass yield was significantly affected by application of blended fertilizer and urea. Fageria et al (2011) also indicated that application of S enhanced the photosynthetic assimilation of N in crop plant. Hence, application of N and S increased the net photosynthetic rate which in turn increased the dry matter and grain yield as 90% of dry weight considered to be derived from products formed during photosynthesis (Barker et al 2007).

Grain yield and harvest index

The analysis of variance showed no significant difference among the fertilized plots but had significantly difference with the control (unfertilized) plot. Therefore, the highest grain yield (2359.1 kg ha^{-1}) was obtained from the application of 150 kg ha^{-1} of NPSB. It had 46.9% yield increment over control and 6.4% over the blanket recommendation (Table 4). The highest grain yield (2359.1 kg ha^{-1}) was higher than the national average yield (15.37 kg ha^{-1}) (CSA 2018). According to report of Tesfahun (2018), grain yield increased consistently and significantly in response to increasing the rate of NPS fertilizer from zero up to 120kg NPS ha-1. This could be due to the combined effect of the balanced nutrient fertilization in blended fertilizer which might have enhanced growth and development of crop compared to the rest of the treatments Tewolde (2018).

Harvest index also showed the same trend with grain yield, there were no significant differences among the treatments with fertilizers while there were significant differences with untreated plots. From the result obtained it was observed that as the level of the fertilizer increased the harvest index decreased indicating low conversion of biomass into grain. Therefore, the highest index was obtained at control plot (Table 4).

Partial budget analysis

To assess the costs and benefits associated with the different treatments, the partial budget technique of International Maize and Wheat Improvement Center (CIMMYT) (1988) was applied. According to this manual, experimental yields are often higher than the yields that farmers could expect using the same treatments; hence in economic calculations researchers have judged that farmers using the same technologies would obtain yields adjusted by 10% lower than those obtained by the researchers if the experiments are planted on representative farmers' fields, (CIMMT 1988). Thus, application of 50 kg ha^{-1}NPSB fertilizer rate for tef biomass yield (Grain + Straw yield) was economically beneficial compared to the other blended fertilizer rates in the study area (Table 5).

Table 6. Economical analysis of the experiment

TRT* Kg/ha	Adj. yield (10% less) (kg/ha)	Total Revenue (TR) [Grain yield*23.8] (1)	Adj. yield (10% less) (kg/ha)	Total Revenue (TR) [Grain yield*3.1] (2)	Gross Revenue Sum (1+2)	fertilizer cost [Birr]	Transport and Application cost [Birr]	Total variable cost (TVC) [Birr]	Net Revenue [TR-TVC]	MRR (ratio) [(Rt2-Rt1)/(Ct2-Ct1)]	MRR (%)
Control (0,0)	1127.79	26841.40	2692.71	8347.401	35188.80	0	0	0	35188.80	0.000	0.0
50NPSB	2070.9	49287.42	5653.44	17525.664	66813.08	1980.25	140	2120.25	64692.83	13.915	1391.5
100NPSB	2078.37	49465.21	5934.42	18396.702	67861.91	2708.85	210	2918.85	64943.06	0.313	31.3
Rec.NP(100:100)	1986.93	47288.93	5493.87	17030.997	64319.93	2918.75	210	3128.75	61191.18	D	D
150NPSB	2123.19	50531.92	6453.72	20006.532	70538.45	3437.45	280	3717.45	66821.00	2.352	235.2
200NPSB	2111.13	50244.89	6799.14	21077.334	71322.23	4166.05	350	4516.05	66806.18	D	D
250NPSB	1958.76	46618.49	6611.76	20496.456	67114.94	4894.65	420	5314.65	61800.29	D	D
300NPSB	2008.89	47811.58	6459.03	20022.993	67834.58	5623.25	490	6113.25	61721.33	D	D

*: GY= grain yield, AY= adjusted yield, TR= total revenue, SY= straw yield, GR= gross revenue, FC= fertilizer cost, ToAC= total and application cost, NR= net revenue and MRR= marginal rate of return

Conclusion and Recommendation

The study revealed the potential advantages of blended fertilizer rates (NPSB) over the N and P blanket recommendation for tef production on different soils of Laelay maichew Woreda. Depending on the results of this study, the following conclusions can be forwarded. Days to 50% heading was significantly affected by rates of blended fertilizer at ($p \leq 0.05$) application as compared with control plot. Hence, plants grown at the rate of 250 kg ha^{-1} NPSB had significantly hastened days to panicle emergence than those grown at the other rates. The number of days to 50% heading recorded over all the treated plots was significantly lower than the unfertilized plot and recommend NP. The analysis of variance showed no significant difference among the treatments received blended fertilizer while there were significant differences ($P \leq 0.05$) with control plot both in plant height and panicle length.

The ANOVA result revealed significance differences ($P \leq 0.05$) of straw yield among the treatments as compared to control. Therefore, the highest straw yield (5880.9 kg ha^{-1}) was recorded from 250 kg ha^{-1} NPSB which showed that the blended fertilizer contributed to enhance the straw yield of tef. This result showed 60.4% straw yield increment over unfertilized plot and 19.2% straw yield increment over recommended NP, respectively. The lowest yield was recorded on control plot in all yield and yield parameters. The ANOVA result also revealed significance difference in grain yield among the fertilized plots and unfertilized plots. Hence the highest grain yield (2359.1 kg ha^{-1}) was recorded from plots that received of 150 kg ha^{-1} of NPSB. This highest yield had 46.9% yield increment over control and 6.4% over the blanket recommendation. While the lowest grain yield (1253.1 kg ha^{-1}) was recorded on control plot. However highest harvest index was obtained from control plots (without any fertilizer).

Based on the results of the study, the following recommendations are forwarded.

- Thus, application of 50 kg ha^{-1} NPSB fertilizer rate for tef biomass yield (Grain + Straw yield) was economically beneficial compared to the other blended fertilizer rates in the study area.
- Impacts of the additional nutrients (sulfur and boron) in the blended fertilizer seem more significantly valued in increasing the biomass production of tef. Thus, a further study across different locations is very important.

References

Adera Sisay (2016): Response of tef [*Eragrostis tef* (Zucc.) Trotter] to different blended fertilizer rates on Vertisols in Jama Woreda, Northeastern Ethiopia. M.Sc. Thesis, Haramaya University, Haramaya, Ethiopia.

Agricultural Transformation Agency (2013): Transforming the use of fertilizer in Ethiopia: Launching the national fertilizer blending program; February 12, 2013.

Agricultural Transformation Agency (2014): Transforming the use of fertilizer in Ethiopia: Launching the national fertilizer blending program

Barker AV and David JP (2007): Hand book of plant nutrition: Books in soil, plant and environment, 177, Taylor and francis press, Boca ratio, London, Newyork.

Berhanu Gebremedhin (2002): Policies for sustainable land management in the highlands of Tigray: Project objectives, activities, organization and database. International Livestock Research Institute.

Bouyoucos J (1962): Hydrometer method improved for making particle size analysis of soil. *Agronomy Journals* (54):464-465.

Bremner JM and Mulvaney CS (1982): Nitrogen - Total. In A.L. Page, R.H. Miller and D.R.Keeney (eds.). Methods of soil analysis. Part 2-Chemical and microbiological properties. Agronomy, 9 (2): 595-624. *American Society of Agronomy*. Madison, Wis.

CIMMYT (International Center for Maize and Wheat Research) (1988): from Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely Revised Edition, Mexico, DF.79 pp.

CSA (Central Statistical Agency) (2017): Agricultural sample survey for the 2015/2016 crop season. Volume II Report on area and production of crops for private peasant holdings (Meher season) Statistical Bulletin 446. FDRE/CSA, Addis Ababa, Ethiopia.

CSA (Central Statistical Agency) (2017): Agricultural sample survey for 2016/17. Statistical Bulletin 532. Addis Ababa, Ethiopia:

Engdawork Assefa (2002): Characteristics, classification and potentials of soils in Werkariya area, South Wollo, Ethiopia. SINET: *Ethiopia Journal of Science*: 25: 45-70.

EthioSIS (Ethiopian soil information system) (2015): http://www.ata.gov.et/highlighted-deliverables/ethiopian-soil-information-system-ethiosis.

Fageria NK Baligar VC Jones CA (2011): Growth and mineral nutrition of field crops.3rdEdn., Taylor &Francis Group, New York, 530 p.

FAO (Food and Agricultural Organization) (2008): Guide to laboratory establishment for plant nutrient analysis, fertilizer and plant nutrition bulletin 19 Rome.

Feyera Asefa, Adugna Debela and Muktar Mohammed (2014): Evaluation of teff [Eragrostis tef (Zuccagni) Trotter] responses to different rates of NPK along with Zn and B in Didessa Woreda, southwestern Ehiopia. *World Applied Sciences Journal* 32: 2245-2249. DOI: http://dx.doi.org/10.19080/artoaj.2016.02.555593

Foth HD (1984): Fundamental of soil science. 7th edition, New York, Chester Brisbone, Toronto, Singapore.

Gomez and Gomez H (1984): Statistical analysis for agricultural research. John Willy and Sons Inc. pp.120-155.

Jackson ML (1967): Soil chemical analysis. Practice Hall of India. New Delhi.

Landon JR (1991): Booker Tropical Soil Manual: A hand book for soil survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical, Essex, New York. 474p. OR John Wiley & Sons Inc., New York

MoA (Ministry of Agriculture) and (Agricultural Transformation Agency) ATA (2014): Soil fertility and fertilizer recommendation atlas for Tigray regional state, Addis Ababa. Ethiopia.

Olsen R, Cole S, Watanabe F and Dean L (1954): Estimation of available phosphorusinsoils by extraction with sodium bicarbonate. United States Department of Agriculture Circ. 939.

Rhoades JD (1982) In Methods of Soil Analysis, Part 2. Second Edition (A.L. Page. Miller and D.R. Keeney, Eds.), American Society of Agronomy. Madison, USA.

Russell EW (1973) Soil Conditions and Plant Growth. 9th ed. New York: Wiley, pp. 1–23

SAS (Statistical Analysis Software) (2002): SAS/STAT User's Guide, Version 9.1.3. SAS institute Inc., Cary, NC

Stewart WM, Dibb DW, Johnston AE and Smyth TJ (2005): The contribution of commercial fertilizernutrients to food production. *Agron J.* 97: 1-6.

Tekalign Tadese (199). Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document. No. 13. International Livestock Research Center for Africa, Addis Ababa.

Tesfahun W (2018): Tef Yield Response to NPS Fertilizer and Methods of Sowing in East Shewa, Ethiopia. *Journal of Agricultural Sciences – Sri Lanka*, 13(2), pp.162–173.

Tewolde Berhe (2018): Validation of blended (NPSB) fertilizer rates on yield, yield components and nutrient uptake of Teff *[Eragrostis tef (Zuccagni) Trotter]* at Vertisols of Hatsebo, Central Tigray, Ethiopia. M.Sc. Thesis, Mekelle University, Mekelle, Ethiopia.

Tsadik Tadele (2016): Supplementary Nitrogen Requirement of Tef [*Eragrostis tef (*Zucc.) *Trotter]* Under Chickpea-tef Rotation at Tahtay Koraro, Northwestern Tigray, Ethiopia. M.Sc. Thesis, Haramaya University, Haramaya, Ethiopia.

Vlek PL (1990): The role of fertilizers in sustaining agriculture in sub-Saharan Africa.*Fert.Res.J*. 26:327-339.

Walkley A and Black LA (1934): An examination of the Degtjareff method for determining soil organic matter and proposed chromic acid titration method. Soil Science, (37):29-38

WoARD (Woreda Agricultural and Rural Development) (2017): Laelay Maichew Woreda Agricultural and rural Development Office.

Response of Newly Released Barley Varieties (*Hordeum Vulgare* L.) to NPS and NPSB Blended Fertilizers adjusted with nitrogen in Degua Temben Woreda, Tigray, Ethiopia

Beyenesh Zemichael* and Kiros Gebretsadkan

Tigray Agricultural Research Institute, Mekelle Agricultural Research Centre, P.O. Box 498, Mekelle, Tigray, Ethiopia

*Correspondence: beyeneshzm@yahoo.com

Abstract

Barley is an important food and beverage crop in the highlands of Tigray, whereas intensive farming and sub optimal fertilizer application have caused nutrient exhaustion and yield deterioration. With this in sight, an experiment was executed to investigate effects of different blended fertilizer rates on yield and yield components of barley (Hordeum vulgare L.) on Vertisols in Degua Temben Woreda, Tigray, Ethiopia. The experiment had seven treatments including two barley varieties (Illala 1 and Illala 2) and five fertilizer combinations viz. control, recommended 100 NPS + nitrogen (N) 46, 50 NPSB +N 23 , 100 NPSB+ N 46 and 150 NPSB +N 69, kg ha^{-1}. The treatments were arranged in randomized complete block design (RCBD) with three replications. The results indicated that yield components and grain yield of barley responded significantly to the application of different rates of blended fertilizers. Significantly higher grain yields of Illala 1(4257 kg ha^{-1}) and Illala 2 (4148 kg ha^{-1}) varieties, respectively were obtained in response to the application of 150 NPSB +69 kg N ha^{-1}. This treatment increased grain yield by about 21% and 14% to 100NPS +N 46 and about 59% over control, for both of the varieties, respectively. The highest net return of Illala 1 (56722.00 Eth-birr ha^{-1}) with MRR of 1102% and Illala 2 (52205.87 ETB ha^{-1}) with MRR of 267% were obtained from application of 150 NPSB+ N 69 kg ha^{-1}. Based on the yield response and partial economic analysis, it is recommended to apply 150 NPSB kg ha^{-1} blended fertilization with 69 kg N ha^{-1} for barley production at Degua Tembien Woreda and in areas with the same soil and agro-ecological conditions.

Keywords: Blended fertilizers, barley varieties, grain yield and marginal rate of return

Introduction

Barley (Hordeum vulgare L.) is one of the most staple food and economically important cereal crop in Ethiopia which ranked fifth next to tef, maize, wheat, and sorghum [Central Statistical Agency (CSA), 2014]. It is a crop with a wide adaptation (Anon, 1972); more drought and disease resistant crop than wheat and is also more productive under adverse conditions (Reddy and Kidane, 1993). However, production of barley in Ethiopia has remained low at below 1.7 t/ha (CSA, 2013) whereas, the potential yield goes up to 6 t/ha on experimental plots (Berhane *et.al*., 1996). Though numerous factors are responsible for low yields, low soil fertility is the most limiting factor that affects plant growth and grain yield. Production of barley in Ethiopia fall under low fertility soils (Yihenew, 2002). Sinebo et al. (2003) reported that about 65% of grain yield variability in barley was attributed to N stress. Likewise, Cantero-Martínez *et al*. (2003) reported that yields of barley under each N and P stresses are reported to be less than 50%. In Ethiopia, fertilizer use trend has been focused mainly on the use and application of N and P fertilizers in the form of Di-ammonium phosphate (DAP) (18-46-0) and urea (46-0-0) or blanket recommendation for the major food crops. Moreover, nutrient mining due to sub optimal fertilizer use in one hand and unbalanced fertilizer (only N and P) uses on other hand have favored the emergence of multi nutrient deficiency in Ethiopian soils (Wassie *et al*., 2011). Recently acquired soil inventory data revealed that Ethiopian soils lack seven soil nutrients (N, P, K, S, Fe, Zn and B) [Ethiopian Soil Information System (Ethio-SIS) 2016].Therefore, different fertilizer materials would be required to ensure balanced fertilizer use involving all or most of the nutrients required by crops for sustainable farming.

Barley is a strategic crop on the rain fed highlands of Tigray, because of its usefulness in farmers’ strategy for risk aversion and as a dependable catch crop at the end of the rainy season in which food is usually scarce. However, farmers are still following their traditional varieties and crop management practices to alleviate the persisting production constraints. There is no information on the application of blended fertilizer rates in the study area. Hence, this experiment was conducted to examine the response of newly released barley varieties to different rates of NPSB fertilizers.

Materials and Methods

Description of the experimental site

The experiment was conducted in DeguaTembien Woreda during 2017 and 2018 cropping seasons. Geographically, the site is located in South Eastern Zone of Tigray. The soil of the experimental site is Vertisols with a textural class of clay loam (45%) (Rowell 1994). According to the rating of Tekalign (1991), the soil reaction (pH) was slightly alkaline (7.7), organic carbon (OC) content was very low (0.49%); and the total N content was very low (0.01%). According to the rating of Cottenie (1980), the available P content was low (100 ppm). Based on the rating of Hazelton and Murphy (2007), the cation exchange capacity (CEC) of the soil was high (37.8 cmol(+) kg^{-1} soil).

Treatments and experimental design

The treatments consisted of five fertilizer combinations viz:[control (no fertilizer application), NPS 100 + N 46, NPSB50 + N 23, NPSB100 + N 46 and NPSB 150 + N 69 kg ha^{-1} and two released varieties of barley Illala 1and Illala 2. The experiment was laid out in RCBD in a factorial arrangement and replicated three times. According~~,~~ to (Ethio-SIS, 2016), nutrients level were 19N - $38P_2O5$ – + 7S in 100 kg of NPS and 18.1N - 36.1 P_2O5 + 6.7 S + 0.71B in that of 100 NPSB. Urea [CO $(NH_2)_2$] (46% N) were used as sources of N.

Experimental procedure and field management

Soil sampling and analysis

Prior to planting, surface soil samples (0–20 cm), from twelve spots across the experimental field were collected, composited and analyzed for soil physicochemical properties following the respective standard laboratory procedures.

Crop management

The experimental field was ploughed three times using ox-driven implements followed by manual seed-bed preparation. All the mineral fertilizers and half of the N fertilizer were applied at planting. The remaining half of the mineral N fertilizer was applied at the tillering stage of growth. Seeds of the barley varieties were hand-drilled at the rate of 100 kg ha^{-1}. The size of each plot was 3 m by 3m ($9m^2$) and distances between rows, plots and replications were 0.2m, 1m and 1.5m, respectively).~~.~~ All recommended cultural practices of barley production were adopted for the management of the experiment. Harvesting was done manually using hand sickles.

Data collection and measurement

Growth and yield related parameters were collected from the net plot area of each plot to avoid border effects. Number of seeds $spike^{-1}$ (NSPS), plant height and spike length were determined from 10 randomly sampled plants per plot at physiological maturity. Data on grain and biomass yields per plot were collected from the middle 13 rows. Aboveground biomass was sun- and air-dried for three days. The grain yield (kg ha^{-1}) was determined after threshing the sun-dried plants harvested from each net plot area and the yield was adjusted to 12.5% moisture content. Harvest index (HI) was calculated as the ratio of grain to the above ground dry biomass yield. Thousand kernel weight was determined by counting the number of seeds randomly taken from each plot

Partial budget analysis

Economic analysis was performed following the International Center for Maize and Wheat Research (CIMMYT) partial budget methodology (CIMMYT, 1988). Economic analysis was done using the prevailing average market prices for inputs at planting and for outputs at the time of crop harvest. The average local market price of barley was 15 Ethiopian Birr (ETB) kg^{-1} and that of the straw was 0.55 ETB $kg^{-1.}$ .The costs of blended fertilizers were 19.30 ETB kg^{-1} and 11.00 ETB kg^{-1} for that of urea. The net benefit (NB) was calculated as the difference between the gross benefit (GB) and the total cost that varied (TCV). Actual grain and straw yields were readjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers would expect to get from the same treatment. Percent marginal rate of return (MRR) was calculated as changes in NB (raised benefit) divided by changes in cost (raised cost).

Data analysis

All data were analyzed following statistical procedures of Statistical Analysis System (SAS) version 9.2. Whenever treatment effects were significant, the means were separated using the least significant difference (LSD) test at 5% level of significance and economic analysis was performed to investigate the economic feasibility of the treatments

Result and Discussions

Effect on phenological parameters of barley

The results of the study indicated that days to heading and maturity were significantly ($P < 0.01$) influenced by the main effects of variety, fertilizer levels and year of cultivation as well as by the interaction effect of fertilizer and year of cultivation (Table1 and 4). Significantly higher number of days to heading (63.7) and maturity (90.3) were recorded in control plots as compared to the lowest number of days to heading (59.4) and maturity (88.5) in plots supplied with NPSB100 +N 46 kg ha^{-1}.Similar results were recorded by cook et.al.1992 who reported that sufficient N results in rapid growth and hastened tasseling, while too little or no N, resulted in slow growth and delayed tasseling in maize. The variety Illala 2 required the longest duration of growth to reach maturity than Illala 1. Thus, the duration required to reach physiological maturity by the variety Illala 2 exceeded the durations required by Illala 1 by about 6.2%.

Days to heading and maturity of barley responded to the fertilizer by year interaction (Table 4). The highest number of days to heading (63.7) in 2018 and maturity (95.7) in 2017 were recorded in control plots as compared to the lowest days to heading (56.5) in 2018 for plots supplied with NPS 100 N46 and maturity (82.2) in 2018 in plots provided with NPSB 100 +N 46 kg ha^{-1} fertilizers. The control plots without fertilizer application delayed heading and maturity of barley by about 13% and 16%, respectively over the control treatment. Whereas use of fertilizer, hastened days to heading and maturity.

Table 1.Mean days to heading, days to maturity and plant height as influenced by fertilizer, variety and year and their interaction.

Fertilizers rate	Days to heading			Days to maturity			Plant height (cm)		
(kg ha^{-1})	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
NPSB0 +N 0	63.8	63.7^{a}	63.7^{a}	92.8^{a}	82.7	90.25	74.6^{c}	57.0^{c}	65.8^{d}
NPSB100+N46	62.7	60.5^{b}	61.6^{b}	94.6^{b}	82.2	88.42	99.6^{a}	83.9^{a}	91.78^{a}
NPS 100 +N 46	62.3	56.5^{c}	59.4^{c}	94.6^{b}	82.3	88.50	91.3^{b}	83.1^{ab}	87.22^{b}
NPSB50 +N23	62.0	57.0^{c}	59.5^{c}	97.3^{ab}	82.2	89.75	86.1^{b}	77.8^{b}	81.93^{c}
NPSB150 N69	61.1	61.8^{ab}	62.1^{ab}	95.6^{ab}	84.0	89.83	104.7^{a}	82.6^{ab}	93.57^{a}
Variety									
Illala 1	61.07	58.53^{b}	59.8^{b}	92.6^{b}	80.7^{b}	86.67^{b}	89.99^{b}	77.3	83.66
Illala 2	64.20	61.27a	62.7^{a}	99.5^{a}	84.6^{a}	92.03^{a}	92.50^{a}	76.4	84.46
Year									
2017			62.6^{a}			96.03a			91.24^{a}
2018			59.9^{b}			82.67b			26.87^{b}
Fertilizer by year			**			Ns			**
CV%	2.3	4.0	3.4	2.3	3.6	2.9	5.0	5.8	5.3

*LSD = least significant difference; CV = coefficient of variation, ** Significant, ns= not significant, Means in a column followed by the same letters are not significantly different at ($P \leq 0.05$)

Growth parameters of barley

Plant height of bread wheat was significantly ($P < 0.01$) responded to the main effect of fertilizer combinations and year of cultivation. However, it was not significantly influenced by any of the interaction effects (Table 1).The tallest barley plants (93.6 cm) were obtained from the application of NPSB150 +N 69 kg ha^{-1}followed by plots supplied with NPS100+ N 46 kg ha^{-1}, respectively. The average heights of plants grown under the aforementioned treatments exceeded the average heights of plants grown in the control treatment by about 42 and 40%, respectively.

Plant heights of barley responded to fertilizer by year interaction. The tallest plant height (104.5cm) were recorded in year 2018 supplied with NPSB150+N69 kg ha^{-1}. Application of

NPSB150+N69 kg ha^{-1} increased the height by 83% compared to the corresponding control plants without fertilizer. The increased plant height in 2018 cropping season could be attributed to better precipitation availability that could have helped in increased uptake of optimum nutrients by plant roots for higher vegetative growth of wheat. Sulfur (S) enhanced the formation of chlorophyll and encouraged vegetative growth and boron (B) helps in N absorption. The results indicated that spike length was significantly ($P < 0.01$) influenced by the main effects fertilizer, variety and year as well as by the interaction effect of variety and year of cultivation. Significantly longer spike length (8.1) were recorded in plots supplied with NPSB150+N69 kg ha^{-1} followed by application of NPSB100 +N 46 as compared to the shortest length in control plots. The variety Illala 2 had longer spike length than Illala 1. Thus, the spike length of variety Illala 2 exceeded the spike length of Illala 1 by about 5%. Spike length was significantly affected by the interaction of variety by year. In this regard, longer spike length was recorded (9.0cm) in year 2017 by the variety Illala 2 as compared to Illala 1 in year 2018. The percentage of increment in spike length due to this treatment was 46% in comparison to the spike length obtained from Illala 1 in 2018.

Yield and yield components of barley

Number of kernels per spike

Number of kernels per spike of barley was significantly ($P < 0.01$) influenced by fertilizer application, variety and year of cultivation. However, this parameter was not significantly influenced by the interaction effects of any of the factors. The maximum number of kernels per spike (22.6) was recorded where fertilizer was applied at the rate of 100 NPS+ N46 kg ha^{-1} followed by plots supplied with the application 150 NPSP +N69 kg ha^{-1}. The aforementioned treatments increased seeds per spike by about 24% and 21%, respectively compared to the corresponding control plants without fertilizer (Table 2). Likewise, the barley varieties also differed significantly ($P < 0.01$) in seeds per spike. Variety Illala 2 produced significantly higher seeds per spike than Illala 1. Thus, seeds per spike by the variety Illala 2 exceeded the seeds per spike of Illala 1 by about 7%.Year also showed significant effect on seeds per spike of barley in which the highest seeds per spike (22.91 cm) was obtained in 2017 which are significantly higher by 20% than those obtained during 2018 crop season.

Table 2. Mean spike length, kernels per spike and thousand seed weight as influenced by fertilizer, variety and year and their interaction.

Fertilizer rates	Spike length(cm)			Seeds per spike(no)			Thousand seed weight (g)		
(kg ha^{-1})*	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
NPSB0N0	7.8d	5.3	6.54^{d}	20.2^{b}	16.37^{d}	18.28^{c}	49.05	44.67	46.86
NPS100N46	9.0b	6.5	7.74^{b}	23.8^{a}	21.43^{a}	22.65^{a}	47.35	45.98	46.67
NPSB50N23	8.8bc	6.3	7.55^{bc}	23.1^{a}	19.80^{b}	21.45^{ab}	48.80	45.50	47.15
NPSB100N46	8.4c	6.1	7.23^{c}	23.2^{a}	18.03^{c}	20.62^{b}	48.43	47.28	47.86
NPSB150N69	9.5a	6.7	8.10^{a}	24.2^{a}	19.83^{b}	22.02^{a}	47.18	44.90	46.04
Variety									
Illala1	8.4	6.15	7.26^{b}	22.03^{b}	18.51^{b}	20.27^{b}	46.79^{b}	45.11	45.95^{b}
Illala2	9.0	6.22	7.61^{a}	23.79^{a}	19.69^{a}	21.74^{a}	49.54^{a}	46.22	47.88^{a}
Year									
2017			8.68^{a}			22.91^{a}			48.16^{a}
2018			6.19^{b}			19.10^{b}			45.67^{b}
Fertilizer *Var	ns	ns	Ns			ns			ns
Var*year			**			ns			ns
CV%	5.6	6.4	5.8	6.0	6.9	7.6	6	3.4	4.9

SL= spike length, SPS= seeds per spike, TSW= thousand seed weight, LSD = least significant difference; CV = coefficient of variation, ns= not significant, Means in a column followed by the same letters are not significantly different at ($P \leq 0.05$)

Total aboveground biomass yield

Biomass yield was significantly ($P < 0.01$) influenced by the main effect of fertilizer application, variety and year as well as by interaction effect of variety by fertilizer and fertilizer by year (Table 3&4). Increasing the rate of fertilizers increased the total aboveground biomass of the barley crop significantly. The highest biomass yield of Illala 1(10016 kg ha^{-1}) and Illala 2 (10072 kg ha^{-1}) varieties, respectively were obtained in response to the application of 150 NPSB +69 kg N ha^{-1}. Besides, the yield obtained in response to the application of NPSB100+N46 were in statistical parity. The lowest biomass yield of Illala 1 (3702 kg ha^{-1}) and Illala 2 (3493 kg ha^{-1}) varieties were recorded for no fertilizer treatment. The highest total aboveground biomass yield increased by about186% and 172% in response to the application of 150NPSB+N69 over the control for Illala 1 and Illala 2, respectively. Likewise, the biomass yield of barley responded significantly ($P < 0.01$) to fertilizer by year interaction. Higher total biomass yield (11412 kg ha^{-1}) were observed during the 2018 cropping season in plots supplied by150 NPSB+ 69 kg N ha^{-1} as compared to 8676 kg ha^{-1} in 2017. The application of 150 NPSB + N 69 kg ha^{-1} in year 2018 increased the aboveground biomass yield by about 31% compared to the corresponding treatment in 2017(Table 4) .This could be attributed to better soil moisture availability that could have helped increased uptake of nutrients by plant roots which may have resulted in increased photosynthetic and vigorous plant growth (Kibe et al 2006).

Table 3. Mean grain yield, biomass yield and harvest index as influenced by fertilizer, variety, year of cultivation and their interaction.

Fertilizers	Grain yield kg $ha^{-1.}$			Biomass yield kg $ha^{-1.}$			Harvest index%		
(rate kg ha^{-1})*	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
NPSB0N0	1912^{e}	1556^{d}	1734^{d}	4000^{d}	3194^{d}	3597^{d}	0.48	0.49^{a}	0.46
NPS100N46	3492^{b}	3631^{b}	3562^{b}	7435^{b}	9201^{b}	8318^{b}	0.47	0.39^{c}	0.47
NPSB50N23	3084^{c}	3852^{b}	3468^{b}	6343^{c}	9628^{b}	7985^{b}	0.49	0.40^{c}	0.47
NPSB100N46	2735^{d}	2997^{c}	2866^{c}	5889^{c}	6786^{c}	6338^{c}	0.47	0.44^{b}	0.47
NPSB150N69	3999^{a}	4406^{a}	4203^{a}	8676^{a}	11412^{a}	10044^{a}	0.46	0.39^{c}	0.46
Variety									
Illala1	2985	3158^{b}	3071^{b}	6307	7900.9	7104^{b}	0.48	0.41^{b}	0.46
Illala2	3104	3419^{a}	3262^{a}	6630	8188.0	7409^{a}	0.47	0.44	0.47
Year									
2017			3044b			6469^{b}			0.48^{a}
2018			3288^{a}			8044^{a}			0.46^{b}
Fer*Var	ns	**	**	Ns	**	**			ns
Fer*year			**			**			ns
CV%	7.0	7.7	6.5	8.4	5.3	6.5	6.0	7.9	3.9

Means in a column followed by the same letters are not significantly different at ($P \leq 0.05$) LSD = least significant difference; CV = coefficient of variation, ns= not significant, **=significant

Grain yield

The grain yield of barley responded significantly ($P < 0.01$) to the main effect of fertilizer, variety and year of cultivation as well to the interaction effect of fertilizer by variety and fertilizer by year (Table 1 and 2). The highest grain yields of Illala 1(4257 kg ha^{-1}) and Illala 2 (4148kg ha^{-1}) varieties, respectively were obtained in response to the application of 150 NPSB + 69 kg N $ha^{-1.}$ .The respective increments in grain yield over the grain yield obtained in control was about 142% for both the varieties. This result is similar with the finding of Melkamu *et al*, 2019 who found maximum aboveground biomass from 200NPSB kg ha^{-1} of blended fertilizer application. Likewise, the grain yield of barley responded significantly ($P < 0.01$) to fertilizer by year interaction. Higher grain yield (4566kg ha^{-1}) was observed during the 2017 cropping season in plots supplied by150 NPSB+ 69 kg N ha^{-1} as compared to 4247 kg ha^{-1} in 2018 of the same treatment. The application of 150 NPSB + N 69 kg ha^{-1} in year 2017 increased grain yield by about 7% compared to the corresponding treatment in 2018 (Table 4).This might be attributed to excess vegetative growth at the expense of reproductive growth, but decreased number of grains that may have negatively reduced yield. It might be associated to increased lodging in 2018 as described by Tripathi et al (2003).

The highest grain yields in 2017 than in 2018 might be attributed to high rates of grain filling during the former than the latter, which may have enhanced better growth and development of the barley plants. In both seasons, the highest and lowest response of barley to fertilizer application was consistent. The highest grain yield increased by about109% and 283% over the control, for the respective years. The increment in the grain yield in response to the increased application rates may be due to the predominant role of fertilizers which plays in enhancing the physiological functions of plants through promoting leaf expansion, photosynthesis, and dry matter accumulation. Similar results were recorded by Woubshet et al (2017) who reported that application of 150 kg ha^{-1} NPSB blended fertilizer with compost increase the grain yield by 4.8 t ha^{-1}.

Table 4. Interaction effect of fertilizer by year on yield and yield components of barley varieties at Degua tembien

Fertilizer rates by year (Kg ha^{-1})*	DTH (d)	DTM (d)	PTH (cm)	SPL cm)	TSW (g)	HI %	BYLD Kg ha^{-1}	GYLD Kg ha^{-1}
Y1(NPSB0+N0)	63.8	97.8	74.6	7.8	44.8	0.46	4000	1568
Y1 NPS100+N46	62.3	94.7	91.3	8.8	44.9	0.39	6343	3640
Y1 NPSB50+N23	62.0	92.3	86.1	8.4	45.8	0.43	5889	2816
Y1 NPSB100+N46	62.7	94.7	99.6	9.0	45.1	0.37	7435	3199
Y1 NPSB150+N69	62.3	95.7	104.6	9.5	44.9	0.39	8676	4566
Y2 NPSB0+N0	63.7	82.7	57.0	5.3	44.6	0.52	3194	1543
Y2 NPS100+N46	56.5	82.3	83.1	6.3	46.1	0.41	9628	4064
Y2 NPSB50+N23	57.0	82.2	77.8	6.1	48.7	0.46	6786	3178
Y2 NPSB100+N46	60.5	82.2	83.9	6.5	46.8	0.41	9201	4063
Y2 NPSB150+N69	61.8	84.0	82.0	6.7	44.9	0.38	11412	4247
Fert*year LSD (0.05)	2.4	3.1	5.3	0.5	Ns	0.04	173.2	266
CV (%)	3.4	2.9	1.1	5.8	6.9	3.9	6.5	7.2

Y1= year 1(2017), Y2= year 2(2018), DTH= days to heading, DTM= days to maturity, PTH= plant height, SL= spike length, SPS= GYLD= grain yield, BYLD = biomass yield, TSW= thousand seed weight, HI= harvest index, CV = coefficient of variation, ns= not significant

Harvest index

Harvest index of barley was not significantly influenced by the main effects but influenced by year and fertilizer interaction (Table 4). The HI ranged from 0.37 to 0.52 with the maximum values recorded in 2018 from control plot. This indicates that biomass partitioning to the grains was lowerunder higher N rates.The higher barley HI in 2018 might be due to higher transfer of assimilates to the grain.

Table 5. Effects of blended fertilizers on economic profitability of barley, Degua Tembien

Variety by fertilizer rates (kg ha^{-1})	Adjusted grain yield kg ha^{-1}	Field Benefit ETB ha^{-1}	Adjusted Straw kg ha^{-1}	Straw Field benefit (ETB ha^{-1})	Gross Field Benefit (ETB ha^{-1})	TVC ETB ha^{-1}	NB (ETB ha^{-1})
Illala-1 NPSB0N0	1582.2	23733	1749.6	962.28	24695.3	0	24695.3
Illala-1 NPS100N46	3018.6	45279	4022.1	2212.15	47491.2	2385	45106.2
Illala-1 NPSB50N23	2460.6	36909	2974.5	1635.97	38545.0	1213	37332.0
Illala-1 NPSB100N46	2928.6	43929	4217.4	2319.57	46248.6	2428	43820.6
Illala-1 NPSB150N69	3831.3	57469.5	5183.1	2850.70	60320.2	3598	56722.2
Illala-2 NPSB0N0	1539.0	23085	1604.7	882.58	23967.6	0	23967.6
Illala-2 NPS100N46	3223.8	48357	4108.5	2259.67	50616.7	2385	48231.7
Illala-2 NPSB50N23	2698.2	40473	3274.2	1800.81	42273.8	1213	41060.8
Illala-2 NPSB100N46	3483.0	52245	4343.4	2388.87	54633.9	2428	52205.9
Illala-2 NPSB150N69	3733.2	55998	5331.6	2932.38	58930.4	3598	55332.4

TCV= total cost that vary, NB= net benefit, ETB= Ethiopian Birr

Partial budget analysis

The economic analysis revealed that highest net benefit of 56722.20 and 55332.40 ETB per hectare was earned from the application rate of 150 NPSB + 69 N kg ha^{-1} for variety Illala I and Illala 2, respectively (Table 5). In this study, the marginal rates of returns from application rates of NPSB50 + N23, NPSB100 + N46 and NPSB150 + N69 kg ha^{-}1 were 1041%, 8663% and 1102%, respectively for the variety Illala 1. The corresponding values from application rates of NPSB50 + N23, NPS100 + N46, NPSB100 + N46 and NPSB + 150N69 kg ha^{-1}were 1409%, 612% 9242% and 267% for variety Illala 2. The results of the economic analysis indicated that applying NPSB150 + N69 kg ha^{-1} resulted higher net benefit and acceptable rate of marginal return. The variety Illala 1 had 8.6% higher net benefit returnvalues attributed to its higher yield (Tale 6).

Table 6. Effects of blended fertilizers on marginal rate of return of barley over years, Degua Tembien,

Variety by Fertilizer (rates kg ha^{-1}) *	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	raised cost (ETB ha^{-1})	raised benefit (ETB ha^{-1})	MRR %
Illala-1 NPSB0+N0	0	24695.2	0	-	-
Illala-1 NPSB50+ N23	1213	37331.9	1213	12636.7	1041.8
Illala-1 NPS100+N46	2385	45106.1	1172	7774.2	663.3
Illala-1 NPSB100+ N46	2428	43820.5	43	D	D
Illala-1 NPSB150+N69	3598	56722.2	1170	12901.6	1102.7
Illala-2 NPSB0+N0	0	23967.5	0	-	-
Illala-2 NPSB50+N 23	1213	41060.8	1213	17093.2	1409.2
Illala-2 NPS100+N46	2385	48231.6	1172	7170.9	611.8
Illala-2 NPSB 100 +N 46	2428	52205.8	43	3974.2	9242.3
Illala-2 NPSB150+N69	3598	55332.3	1170	3126.5	267.2

TCV= total cost that vary, NB= net benefit, MRR= marginal rate of return, ETB= Ethiopian Birr

Conclusion and Recommendations

The result of the present study revealed that different blended fertilizer rates markedly affected yield performance of the improved barley varieties. Fertilizer application at the rate NPSB150 + N 69kg ha^{-1} was found to produce higher grain and total above ground biomass yield of both varieties at both seasons. Maximum grain yield of (4257.1 kg ha^{-1}) was recorded from the application of NPSB150 + N69 for $Illala^{-1}$ followed by $Illala^{-2}$ with a yield of 4148.2 $kgha^{-1}$.The lowest grain yield of 1710 kg ha^{-1} was recorded from control (unfertilized check) of the same variety $Illala^{-2}$ followed by Illala 1 with a yield of 1758 kg ha^{-1}, The maximum rate of return of (1102 %) was obtained with the application of NPSB150 +N $69ha^{-1}$with a net benefit of 56722.2 ETB ha^{-1}which is attributed to its higher yield. For Illala 2 the maximum MRR of (9242%) was obtained with the application of NPSB 100 +N 46 kg ha^{-1} with a net benefit of 52205.87 ETB ha^{-1}. However, the acceptable marginal rate of return (267%) and the highest net benefit (55332.38 ETB ha^{-1}) was obtained from NPSB150 + N69 for Illala-2. The results of the economic analysis indicated that applying NPSB150 + N 69kg ha^{-1} resulted in the acceptable rate of marginal return and higher net benefit and the variety Illala 1 was the one that performed best.

Acknowledgements

The Authors thank Mekelle Agricultural Research Center for providing the necessary resources to conduct the study. The authors wish to express their appreciation to Soil Fertilitility Laboratory case team members of Mekelle Soil Research Center for their unreserved collaboration and assistance during soil analysis.

References

Anon I (1972): Crop production in dry regions: systematic treatment of the principal crops vol.II. intertext, Leonard Hill, London, 682p.

Berhane Lakew Hailu Gebre and Fekadu Alemayehu (1996): Barley production and research. pp 1–8, *in:* Hailu Gebre and J.A.G. van Leur (eds.). *Barley Research in Ethiopia: PastWork and Future Prospects*. Proceedings of the 1st Barley Research Review Workshop, 16–19 October 1993, Addis Ababa. IAR/ICARDA, Addis Ababa, Ethiopia.

Cantero-Martı´nez C Angas P and Lampurlanes J (2003): Growth, yield and water productivity of barley (Hordeum vulgare L.) affected by tillage and N fertilization in Mediterranean semiarid, rain fed conditions of Spain. *Field Crops Research,* 84: 341–357.

CIMMYT (International Maize and Wheat Improvement Center) (1988): From Agronomic Data to Farmers Recommendations: Economics *Training Manual*. Completely Revised ed, CIMMYT, Mexico. D.F.

CSA (Central Statistical Authority) (2014):The Federal Democratic Republic of Ethiopia Central Statistical Agency. Agricultural sample survey, report on area and production of major crops, Addis Ababa, Ethiopia

CSA (Central Statistical Agency) (2013): Results on area, production and yield of major crops by sector and season. Agricultural Sample Survey. CSA, Addis Ababa, Ethiopia.

Cock R L and Ellis BG (1992): Soil management, a world view of conservation Krieger Publishing Company, Malabar, Florida. 413 p.

Ethio-SIS (Ethiopia Soil Information System) (2016): Fertilizer Recommendation Atlas of the Southern Nations, Nationalities and Peoples' Regional State, Ethiopia. Pp 81.

Hazelton P and Murphy B (2007): Interpreting soil test results: what do all the numbers mean? CSIRO PUBLISHING, Collingwood VIC, Australia.152 p.

Institute of Agriculrural Research (IAR) (1979): Mekelle research station, Northern region, progress report April 1975 to Dec 1976, Addis Abeba, Ethiopia

Kibe AM Singh S. and Kalra, N (2006): Water–nitrogen relationships for wheat growth and productivity in late sown conditions. *Agriculture Water Management,* 84: 221-228.

Melkamu HS Gashaw M and Wassie H (2019): Effects of different blended fertilizers on yield and yield components of food barley (Hordeum Vulgare L.) on Nitisols at Hulla Woreda, Southern Ethiopia. Acad. Res. J. Agri. Sci. Res. 7(1): 49-56.

Reddy MS and Kidane Georgis (1993): Dry land farming research in Ethiopia: review of the past and thrust in the nineties, IAR, Addis Ababa, Ethiopia

Rowell D (1994): Soil Science; Methods and Application. Longman Scientific and Technical, 350p.

Tekalign Tadese (1991): Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13.International Livestock Research Center for Africa, Addis Ababa.

Tripathi SC Sayre KD Kaul JN and Narang RS (2003): Growth and morphology of spring wheat (*Triticum aestivum L.)* Culms and their association with lodging: effects of genotypes, N levels ethephon. *Field Crops Research*, 84, 271-290.

SAS (Statistical Analysis System) Institute (2003):. "SAS Version 9. 1.2 © 2002-2003". SAS Institute, Inc., Cary, North Carolina, USA.

Wassie Haile and Shiferaw Boke (2011): Response of Irish potato (Solanum tuberosum) to the application of potassium at acidic soils of Chencha, Southern Ethiopia. International Journal of Agricultural Biology13: 595–598.

Woubshet D Selamyihun K and Cherukuri V (2017): Effect of integrated use of lime, blended fertilizer, and compost on productivity, nutrient removal and economics of barley (Hordeum vulgare L.) on acid soils of high lands in West Showa Zone of Ethiopia. Int. J. of Life Sciences, 2017, Vol. 5 (3): 311-322

Yihenew G (2002): Selected chemical and physical characteristics of soil Adet Research Center and its testing sites north-western Ethiopia.

Effect of Blended NPSZn Fertilizer Levels with Adjusted N on Yield and Yield Components of Barley on Cambisols of Enda-Mokeni, Northern Ethiopia

Hagos Brhane*, Sofonyas Dargie, Fisseha Hadgu, Tsigabu Mehari, Molla Hadis and Daniel Berhe

Tigray Agricultural Research Institute, Mekelle Soil Research Center, P. O. Box 1070, Mekelle, Ethiopia

*Correspondence: hagosb7@gmail.com

Abstract

Field experiments were conducted to evaluate the effects of blended NPSZn levels on yield and yield components of barley in Edna-Mokeni Woreda. The experiments were laid out in Randomized Complete Block Design (RCBD) with seven blended NPSZn levels (0, 50, 100, 150,200,250,300 kg ha^{-1}) and blanket recommendation of nitrogen (N) and phosphorus (P) in three replications for two consecurive years (2017 and 2018). Results depicted that highest plant height, grain yield and straw yield of barley increased with blended levels and the highest was obtained at 300 kg ha^{-1}. However, this level was statistically similar with the levels of 100 and 250 kg ha^{-1} in grain yield and 150, 200 and 250 kg ha^{-1} in the straw yield. Moreover, the result of blanket recommendation of N and P was statically similar with that of the NPSZn range of 100 - 250 kg ha^{-1} in grain and straw yields of barley. However, the levels of P in blended (150-250 kg ha^{-1}) were much higher than in the blanket N and P. Hence, from this point of view, we might say that the incorporation of S and Zn in the blended had no significance effect on the grain and straw yield of barley. Both biological yield and partial budget analysis revealed that 100 kg ha^{-1} NPSZn with 100 kg urea ha^{-1} was found economical in the study area. Further research should be conducted on N and P interactions with the fertilizers in the blended such as S and Zn.

Keywords: Blended, Yield, Barley, Enda-Mokoni

Introduction

Cultivation of barley is a common farming practice in Ethiopia. Based on areas of production and yield per unit area, barley is ranked 5th and 4th, respectively among all cereals in Ethiopia [Central Statistical Agency (CSA) 2014]. However, the average national yields are low (about 1870 kg/ha) as compared to world average cereal yields of 4000 kg/ha (Eyasu and van Beek 2015). Nutrient depletion is one of the major causes that contribute to decline in soil productivity of Ethiopia (Kebede and Yamoah 2009). Fertilization is one of the most important notable measures to replace the depleted nutrients (Kabir 2011). Inline to this, Brhane and Teka (2018) reported that balanced fertilization with an optimum application rate is necessary to improve soil fertility and thus increasing the productivity of crops including barley.

Among the key strategies that were identified to help increase agricultural production and productivity in Growth and Transformation Plan (GTP) period was the soil fertility mapping of the country's agricultural lands. The necessity to transform agricultural sector with respect to soil fertility requires application of proper amounts of balanced fertilizers for different crops. Inline to this, blended fertilizers containing N, P, S, boron (B), iron (Fe) and Zn in blended form have been recommended to solve site specific nutrient deficiencies and thereby to increase crop production and productivity. The major recommended blended fertilizers for Tigray region were NPS, NPSB, NPSZn, NPSZnB, NPSFeZn and NPSFeZnB [Ethiopian Soil Information System (EthioSIS), 2014]. Though potassium (K) was part of the previous blended fertilizer, recently it was suggested to be applied based on soil test result.

Although the type of required blended fertilizers are identified for the region, optimum rates of the major recommended blended fertilizer types for different crops, agro ecologies and soil types are not yet determined. Besides, verifying the soil fertility map for major crops grown in the region in different agro ecologies and on different soil types is urgently needed to increase crop yields and to improve quality of major crops grown in Tigray. Therefore, this experiment was conducted with the aim of investigating the effects of NPSZn blended fertilizer on yield and yield components of barley among the recommended blended fertilizers for Tigray.

Materials and Methods

Description of study area

The studies were conducted on Cambisols of Edna Mokeni WoredaWoredas in southern zone of Tigray region, northern Ethiopia (Figure 1). The Woreda is extended between 39^0 18’ 10’’ E to 39^0 39’ 50’’ E and 12^0 33’ 20’’ N to 12^0 55’ 0’’ N with an average altitude of 2250 meters above sea level. The area is characterized by bimodal rainfall pattern and receives a mean annual rainfall of 68.87 mm. The average minimum and maximum temperatures were 22.5 and 10.4 ^{O}C, respectively. Barley, wheat, faba bean, field pea and maize are the major crops grown in the area.

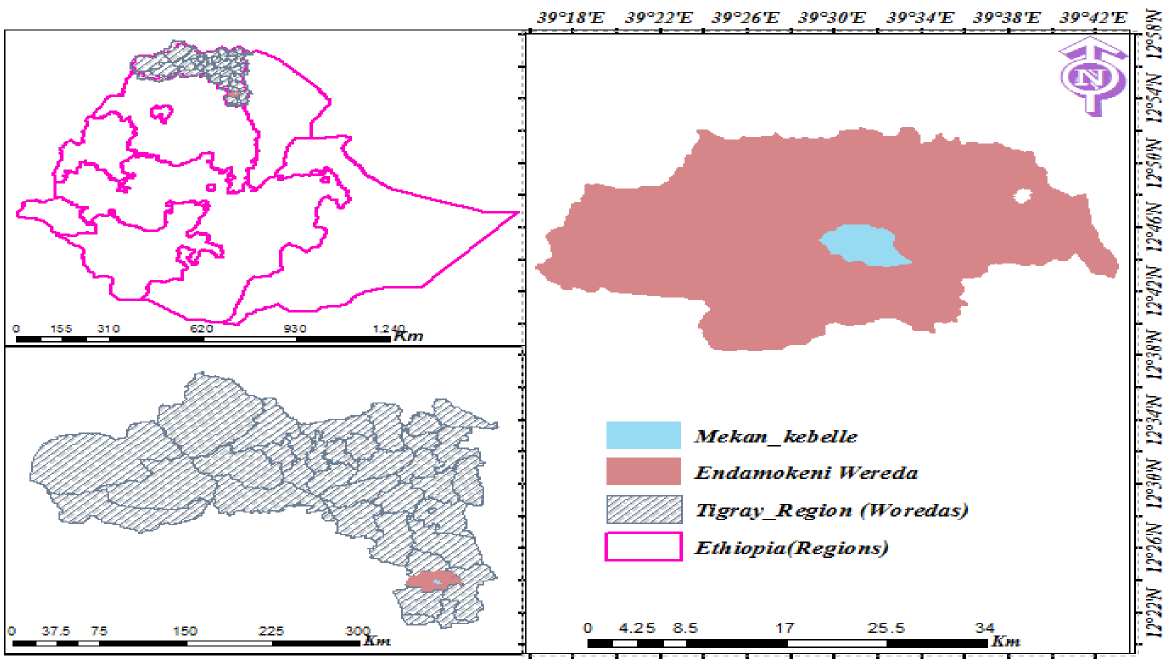

Figure1. Location of the study area at Enda Mekhoni, Southern Tigray, Ethiopia

Experimental design and procedures

The experiments were conducted for two years (2017 and 2018) with two sites in each year. The experiments consisted of 7 level of NPSZn (0, 50, 100, 150, 200, 250 and 300 kg ha^{-1} and blanket recommendation (64 kg N ha^{-1}, 46 kg P_2O_5 ha^{-1}) as 8th treatment. Nitrogen was adjusted to 64 N in all of the treatments except in the control. The experiments were laid out in RCBD with three replications. The blended fertilizer was applied at planting, while the N fertilizers were applied twice during the crop growth stage that is 1/3 of the full dose at planting and the other 2/3 at the full tillering stage. In the trial, Shedeho barley variety was used as test crop.

The initial soils of the experimental fields were analyzed for texture, pH, organic carbon (OC), cation exchange capacity (CEC), total N, available P, available S and available Zn. The methods used for soil physical and chemical analysis were: Soil pH (Rhoades 1982), OC % (Walkley & Black 1934), soil texture by hydrometer (Bouyoucos 1962), available P (Olsen 1954), total N by Kjeldhal method (Bremner & Mulvaney 1982), Neutral Ammonium acetate method (Chapman 1965) for cation exchange. In addition to these, partial budget analysis was made to investigate the economic feasibility of the treatments. Marginal rate of return, which refers to net income obtained by incurring a unit cost of fertilizer, was calculated as the change in net revenue divided by the change in total variable cost levels [International Center for Maize and Wheat Research (CIMMYT) (1988)]

Data collection

Data on growth and yield related crop parameters were collected on plot bases. Data such as plant height, spike length, biomass yield and grain yield were measured and collected. Data related to input and output costs for partial budget analysis were also recorded.

Data analysis

Analysis of variance (ANOVA) was carried out using Statistical Analysis System (SAS) version 9.Whenever treatment effects were significant, mean separations were made using the least significant difference (LSD) test at the 5% level of probability.

Result and Discussion

Initial soil properties of the study sites

The texture classes of the study sites were loam and clay loam. Moreover, based on Tadesse (1991) rating ,the soils pH were neutral, no saline (Ec<2ds/m), and low in total N and OC % .The available P status of the three study sites were high, while the remaining one site were medium (Olsen et al 1954). The CEC of the soils in the study sites were high according to Landon (1991) CEC ratings. On the other hand, deficiencies of S and Zn were reported in the study sites (EthioSIS 2014).

Effect of NPSZn levels on yield and yield components of barley

There were no interaction effects among year, site and fertilizer treatments on yield and yield components of barley response. The main effect of year significantly affected plant height, HI, grain yield and straw yields of barley. Based on the data presented in Table 2 below, all parameters were significantly affected by main effect of year and site. In line to this, year II were significantly better year than year I for the yield and yield components of barley except plant height. This might be due to the climatic variability especially the rainfall and temperature variation between the two years. Similarly, significantly highest grain and straw yields of barley were recorded at site 4. This might be due to the initial combined soil characteristics of the site which was better in CEC, OC%, available P and total N content.

Table 1: Selected physio- chemical properties of surface (0-20cm) fields before sowing

	Experimental sites			
	Year 2017		Year 2018	
Parameters	Site1	Site2	Site 3	Site 4
pH	6.86	7.27	6.62	6.74
EC (ds/m)	0.1	0.15	0.11	0.1
OC (%)	0.9	1.2	1.1	1.5
TN (%)	0.07	0.09	0.06	0.12
Av.P(ppm)	20.06	9.62	15.44	23.60
CEC(meq/100gsoil)	25	26.5	35.40	36.17
% Sand	38	20	28	46
% Silt	36	42	34	28
% Clay	26	38	38	26
Textural class	Loam	Clay loam	Clay loam	Loam

Blended NPSZn level had significantly affected all the measured agronomic parameters of barley. Thus, mean plant height, grain and straw yield of barley had increased with increasing NPSZn application levels even though the trend was not consistent. In line to this, the highest grain and straw yields of barley were recorded at the highest rate of 300 kg ha^{-1} NPSZn blended fertilizer. The recorded yield at this rate is statistically similar with 100 and 250 kg/ha in grain yield and 150,200 and 250 kg ha^{-1} NPSZn blended fertilizer rates in straw yields of barley. The N level in all of the treatments except control was similar, which was adjusted to 64 N.

The blended NPSZn fertilizer levels starting from 100 kg ha^{-1} to 250 kg ha^{-1} gave statically similar grain as well as straw yields of barley with the blanket recommendation of N and P (64 kg ha^{-1} N and 46 kg ha^{-1} P_2O_5). However, the level P in this blended fertilizer ranges from 35 kg ha^{-1} P_2O_5 at 100 kg ha^{-1} to 87.5 at 250 kg ha^{-1} which is higher than the blanket recommendation of N and P. Hence, from this point of view we might say that, the incorporation of S and Zn in the blended fertilizer had no significance on the yield and yield components of barley rather it decreased P efficiency. Had the yield difference been due to the level of S or Zn, significantly higher yields of barley would have been recorded at a rate of NPSZn which has equivalent or lower level of P as compared to the blanket N and P.

Therefore, it is difficult to differentiate the significant grain and straw yields of barley were resulted from which nutrient in the blended NPSZn. Hence, formulation of the blending might be contributed to these random effects since it was not developed through crop response trials.

Table 2. Main effects of year, site and fertilizer treatments (blended NPSZn) on yield and yield components of barley

Year	Plant height (cm)	Spike length(cm)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
I	70.56B	6.65A	3105.99B	3830.1B	0.45B
II	90.88A	5.67B	4224.27A	4706.3A	0.47A
LSD	1.89	0.24	196.93	225.96	0.0109
P value	<.0000	<.0000	<.0000	<.0000	<.0000
Site					
Site 1	70.48C	6.19B	3500.6B	4317.5B	0.45CB
Site 2	70.64C	7.11A	2711.4C	3342.8C	0.45CB
Site 3	92.59A	5.57C	4207.4A	4487B	0.48A
Site 4	89.16B	5.77C	4241.1A	4925.6A	0.46B
LSD	2.67	0.334	278.5	319.56	0.02
P value	0.04	<.0001	<.0001	<.0001	0.031
Treatment					
0	67.73D	5.4B	2227.1C	2847.9D	0.43D
50	78.02C	6.38A	3717.1B	3892.6C	0.49A
100	81.07BC	6.23A	3900.6BA	4289.7BC	0.47BA
150	83.27BA	6.28A	3836.1B	4486.1BA	0.46BC
200	85.08A	6.45A	3839.4B	4603.7BA	0.46BC
250	84.03BA	6.1A	3870.3BA	4690.8BA	0.451CD
300	85.73A	6.17A	4243.2A	4941.6A	0.46BC
Rec.NP	80.82BC	6.26A	3687.4B	4393.2B	0.454BCD
LSD(0.05)	3.72	0.46	393.73	456.24	0.214
P value	<0.0001	0.0008	<0.0001	<0.0001	0.0002
Cv (%)	5.68	9.19	13.23	13.16	5.72

Partial budget analysis

A dominance analysis was conducted to eliminate negative values between succeeding treatments in calculating the marginal rate of return (MRR). The partial budget analysis of the study indicated that NPSZn fertilization gave promoting benefit over the control on barley yield. Results revealed that the marginal rate of return was increasing up to 300 kg ha^{-1} NPSZn. The recorded yield at this rate was statistically similar with 100 and 250 kg ha^{-1} in grain yield and 150, 200 and 250 kg ha^{-1} NPSZn blended fertilizer rates in straw yields. Considering grain yield, 100 kg ha^{-1} NPSZn fertilizers rates would be recommended for optimum barley production and it is statistically at par with the blanket recommendation of N and P. However, both grain and straw yields are economically important in the livelihood of the farmers. As a result, from total biomass perspective, significantly higher yield of barley was obtained at 300 kg ha^{-1} NPSZn rate. The marginal rate of return obtained upto 300 kg ha^{-1} NPSZn showed that further earnings could be obtained beyond application of this level. Among the treatments thus, 300 kg ha^{-1} NPSZn is economically profitable in the current study. This is based on CIMMYT (1988) economic analysis recommendations which stated that application of fertilizer with the marginal rate of return above the minimum level (100%) is economical.

Table 3. Partial budget analysis of barley response to NPSZn fertilizer levels

Fertilizer (kg ha^{-1})	Fertilizer Cost(ETB)	FA and TC (ETB)	TVC (ETB)	GY (kg/ha)	SY (kg ha^{-1})	GR *14	SR *3.2	TR (ETB)	NR (ETB)	MRR (ratio)	MRR(%)
0	0.0	0.0	0.0	2004.4	2563.1	28061.46	8201.95	36263.41	36263.41		
50	2316.9	254.8	2571.7	3345.4	3503.3	46835.46	11210.69	58046.15	55474.45	7.47	747.02
100	2791.6	301.0	3092.6	3510.5	3860.7	49147.56	12354.34	61501.9	58409.28	5.63	563.40
150	3266.4	347.1	3613.5	3452.5	4037.5	48334.86	12919.97	61254.83	57641.3	D	D
Rec NP	3695.1	358.7	4053.8	3318.7	3953.9	46461.24	12652.42	59113.66	55059.87	D	D
200	3741.2	393.3	4134.4	3455.5	4143.3	48376.44	13258.66	61635.1	57500.65	D	D
250	4216.0	439.4	4655.4	3483.3	4221.7	48765.78	13509.50	62275.28	57619.93	D	D
300	4690.7	485.5	5176.3	3818.9	4447.4	53464.32	14231.81	67696.13	62519.85	1.97	197.28

Conclusion and Recommendation

Results indicated that NPSZn fertilization had significantly influenced yield and yield components of barley in the study sites. Hence, the highest plant height, grain and straw yield of barley were obtained at the highest level of NPSZn (300 kg ha^{-1}) even though, it is statistically similar with 100 and 250 kg ha^{-1} NPSZn in grain yield and 150, 200 and 250 kg ha^{-1} in straw yield. However, it is difficult to differentiate whether the yield difference were due to S and Zn in the blended or due to other random factors. Besides, partial budget analysis result also revealed that application of 300 kg ha^{-1} NPSZn fertilizer is economically optimum rate for the area. Therefore, based on the results of the study and the above summary the following recommendations were set. Application of NPSZn fertilizer at a rate of 100 kg ha^{-1} with 100 kg of urea ha^{-1} is economically feasible to improve the productivity of barley in Edna Mokeni. Further research should be conducted to evaluate the interaction effect of N and P with other nutrients in the blend such as S and Zn in elemental bases not as a blended form to gain optimum interaction formulations.

Acknowledgements

The authors are grateful to AGP II (Agricultural Growth Program II) for their financial support.

References

Bouyoucos G J (1962): Hydrometer method improved for making particle size analyses of soils. Agronomy Journal, 54: 464–465.

Bremner J M and Mulvaney C S (1982): Nitrogen-total. In Methods of soil analysis, Part 2. Chemical and microbiological properties (methods of soilan2), (pp. 595–624).

Brhane H and Teka K (2018): Optimum K fertilizer level for growth and yield of wheat (Triticum aestivum) in Cambisols of Northern Ethiopia. *Asian Research Journal of Agriculture*, pp.1-8.

Chapman H D (1965): Cation-exchange capacity. In Methods of soil analysis. Part 2. Chemical and microbiological properties, (methodsofsoilanb) (pp. 891–901).

CIMMYT (International Center for Maize and Wheat Research) (1988): From agronomic data to farmer recommendations. An economics training manual (No. 27). Mexico CIMMYT.

Eyasu E and van Beek C (2015): Scaling Innovations and Agricultural Best Practices in Ethiopia: Experiences and Challenges.

CSA (Ethiopian Central Statistical Agency) (2014): The Federal Democratic Republic of Ethiopia Central Statistical Agency. Agricultural sample survey, report on area and production of major crops, Addis Ababa, Ethiopia.

EthioSIS (Ethiopia Soil Information System) (2014): Soil fertility status and fertilizer recommendation atlas for Tigray regional state, Ethiopia.

Kabir M H Talukder NM Uddin MJ Mahmud H and Biswas B K (2011): Total Nutrient Uptake by Grain plus Straw and Economic of Fertilizer Use. *Journal of Environmental Science and Natural Resources*, *4*(2), pp.83-87.

Kebede F and Yamoah C (2009): Soil fertility status and numass fertilizer recommendation of typic hapluusterts in the northern highlands of Ethiopia. *World Applied Sciences Journal*, *6*(11), pp. 1473-1480.

Landon J R (1991): Booker tropical soil manual: A handbook for soil survey and agricultural land evaluation in the tropics and sub-tropics (p. 474). Essex, NY: Longman Scientific and Technical.

Olsen S R (1954): Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Washington: United States Department of Agriculture.

Rhoades J D (1982): In Methods of soil analysis, part 2 (2^{nd} ed., A. L. Page, Miller, & D. R. Keeney, Eds.). American Society of Agronomy, Madison.

Tadesse T, Haque I and Aduayi E A (1991): Soil, plant, water, fertilizer, animal manure and compost analysis manual (ILCA/PSD Working Document (ILCA)). Addis Ababa.

Walkley A and Black I A (1934): An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science*, *37*, 29–38.

Comparative Analysis of Maize Yield and Economic Returns of Fertilizer Microdosing in Tigray, Northern Ethiopia

Alemtsehay Tsegay[1]*, Girmay Kiros[2], Girmay Tesfay[1] and Yemane Gebregziabher[1]

[1]Mekelle University, College of Dryland Agriculture and Natural Resources, P.O. Box 231, Mekelle, Tigray; [2] Tigray Water, Mines and Energy office, P.O.Box 520,Mekelle, Tigray,

[1*]Correspondence: alemtsehay.tsegay@gmail.com

Abstract

Yield and economic response of microdosing of blended, di-ammonium phosphate (DAP) and urea fertilizers were investigated on maize (Zea mays L.) production at Hintalo-Wajerat Woreda, Tigray, Northern Ethiopia. The field experiment was conducted under irrigation condition in 2017. Randomized complete block design (RCBD) was used to arrange 11 treatments with three replication. The treatments were: blended fertilizer at a rate of 100%, 50%, 25% and 10% of the recommended rate applied in microdosing, microdosing of DAP and urea at the corresponding rates, broadcasting of blended fertilizer, DAP and urea at a rate of 100%, and control (without fertilizers). All agronomic data were collected and subjected to statistical analysis. The profitability of microdosing was evaluated using partial budget analysis. The results revealed that microdosing of blended, DAP and urea fertilizers at different rates were significantly different ($P \leq 0.01$) from broadcasting of the same fertilizers on days to 75% flowering, silking, 90% maturity, yield and yield components of maize. Early flowering and silking were recorded from microdosing of blended fertilizer at a rate of 100% followed by 50% compared with control. Similarly, microdosing of blended fertilizer at a rate of 100% and 50% increased plant height by 34.86% and 35.32%, respectively as compared to DAP and urea (100%) applied in broadcasting. Likewise, the 1000 seed weight (0.45 kg), aboveground biomass (12.3 t/ha), cob length (19.3 cm) and grain yield (8.42 t ha^{-1}) were higher in microdosing of blended fertilizer at a rate of 100%. With regard to the cost-effectiveness, the highest marginal rate of return (100.35%) was obtained from microdosing of blended fertilizer at a rate of 50%, which could be recommended as best practice to the farmers. However, this experiment needs to be further repeated across locations.

Key words: Blended, Broadcasting, Maize, Microdosing

Introduction

Maize (*Zea mays* L.) cultivated all over the globe is belonging to family *Poaceae* and is the third most important cereal crop next to rice and wheat. Although the introduction of the crop to Ethiopia is a recent phenomenon as compared to the indigenous cereal crops, it is believed that it is introduced between 1600s and 1700s (Huffnagel 1961) and produced as one of the major cereal crops in the country. The crop is used in the traditional diets in the form of *Injera, Kitta, Kollo, Nifro* and local beverage called *Tella* and accounts for 16.7% of the national calorie intake followed by sorghum (14.1%) and wheat (12.6%) among the major cereals (Berhane et al 2011). Furthermore, it is also an important component of animal feed (40%) in tropical areas and up to 85% in developed countries (McCutcheon 2007).

According to Ethiopian Agricultural Sample Survey of 2017/2018 [Central Statistical Agency (CSA), 2018], maize stood 2nd in area coverage (16.8%) following tef and 1st in production (17.26%) among cereal crops. Although the crop grows from moisture stress areas to high rainfall areas and from lowlands to the highlands (Wondesen and Sheleme 2011). The report of CSA indicated that the average yield of maize in Ethiopia is low (3.94 tha^{-1}) as compared to world average (6.7 t ha^{-1}) production (Khalily et al 2010). In Tigray, wherein this research was conducted, maize is widely grown with an area of 62,161.8 ha of land accounting 6th in area coverage and 2nd in production compared with the major cereals grown in the region. The average yield is 2.56 t ha^{-1} which is below the national average (CSA 2018). This could be among others, as a result of declining soil nutrient availability especially nitrogen (N) and phosphorus (P), poor agronomic practice (like inappropriate fertilizer rate and method of application, use of poor seed quality), insect and disease problems.

The most common fertilizers used in Ethiopia in general and particularly in Tigray region were DAP and urea as source of P and N, respectively. However, currently blended fertilizers that contain both macro and micro nutrients are introduced and are under use (Ministry of Agriculture and Ethiopian Agricultural Transformation Agency 2014). As per this document, a blended fertilizer that contains N, P, Sulphur (S), Potassium (K) and Zinc (Zn) is recommended to Village *Andi-Weyane,* situated in Hintalo-Wajerat Woreda, wherein this study was conducted but the optimal rate of this fertilizer is not yet validated. Additionally, these fertilizers are commonly applied in broadcasting for broadcasted crops and banding for row-planted crops. These have been therefore a growing interest to find alternative interventions (microdosing), which promotes efficient and sustainable use of fertilizers tailored to smallholder farmers.

Microdosing is localized application of small quantities of fertilizer during planting or three to four weeks after emergency as top dressing (Camara et al 2013, Hayashi et al 2008; Tabo et al 2007). Thus, knowledge on the roles of microdose fertilizer application and their optimal rate is important to maximize grain yield and protect the residual effect of fertilizes on the environment. Therefore, the objective of this study was to evaluate the agronomic and economic advantage of microdosing of blended fertilizer at different rates as compared to DAP and urea fertilizers on yield and yield components of maize.

Materials and Methods

Description of the study area

The experiment was conducted at village *Andi-weyane,* which is located in Hintalo-wejerat Woreda, Tigray region, Northern Ethiopia (Figure 1). The site is situated at 39°17'39"-39°22'50"E and 13°15'50"-13°19'35"N and has an altitude of 2300 m a.s.l. The mean total annual rainfall of the study area ranged 450 to 600 mm (BoARD 2015). This area is characterized by high irrigation potential where different crops including maize are growing.

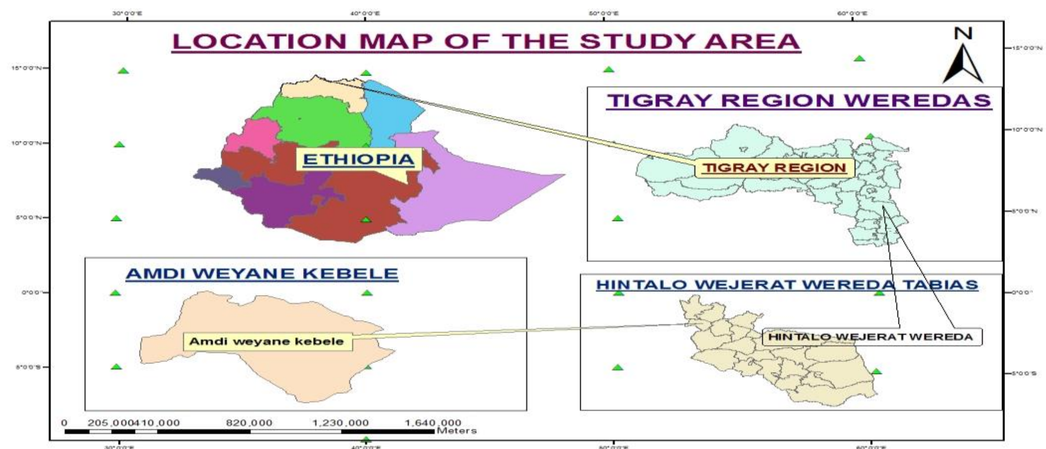

Figure 1. Location map of the study area at Hintalo Wejerat, Tigray, Ethiopia

Experimental design and treatments

The field experiment was conducted under irrigation in 2017. The experimental plots were arranged in a RCBD with three replications. The treatments included were: blended fertilizer at a rate of 100%, 50%, 25% and 10% of the recommended rate applied in microdosing, microdosing of DAP and urea fertilizers at the corresponding rates, broadcasting of blended fertilizer at the rate of 100%, broadcasting of DAP and urea at 100% and Control (without fertilizers). The blended fertilizer contains NPKSZn with 15, 31, 8, 7 and 2.2 kg ha^{-1} of the respective nutrients and was used as a base for the different rates. However, additionally, 100, 50, 25 and 10 kg ha^{-1}of urea were applied to the four levels of the corresponding blended fertilizer rates to full fill the recommended dose of N for the crop. The recommended rate of DAP and urea for the crop was

100 kg ha^{-1}each that accounts 64 kg ha^{-1} of N and 46 kg ha^{-1} of P_2O_5.The full dose of blended fertilizer and DAP were applied at sowing while urea was applied in split (50% at sowing and 50% top dressing at the knee stage of the crop).

Maize, variety *Melkasa 2* was used as a test crop. *Melkasa 2* is an early maturing maize variety released in 2003 and is recommended to the dryland ecology of the country (EARO 2004). A plot size of 2 m by 3.75 m was used with a spacing of 1m and 0.5m between blocks and plots, respectively. Distance of 75 cm between rows and 25 cm between plants were used. The land was ploughed three times (using oxen) before sowing as per the practice of the farmers in the study area. Other agronomic practices like weeding and inter row cultivation were done uniformly to all plots. Irrigation was done at seven days interval based on the observation of the soil wetness as per the practice of the farmers.

Data collection and analysis

Crop data

Phenological crop data recorded includes days to 75% tasseling, 75% silking, 75% flowering and 90% maturity. Days to 75% tasseling, silking and flowering dates were recorded by visual observation from planting to 75% get tasselled, extrusion of silks and anther shown, respectively. Similarly, days to 90% maturity was recorded when 90% of the plants reached physiological maturity. The data for plant height, cob length, cob number per plant were recorded from five randomly sampled plants of central rows per plot. Dry aboveground biomass and grain yield (kg ha^{-1}) were recorded after the plants were harvested from the central three rows and extrapolated on hectare bases. Thousand grainsweight was measured by counting 1000 seeds and weighed using sensitive balance after the grain seeds get constant moisture content. All collected data were subjected to statistical analysis using Genstat software (Payne et al 2011). Significantly different treatment means were separated using the Duncan's Multiple Range Test at 5% level of probability. Pearson's correlation coefficient was used determined the association among the different growth, yield and yield component of maize**.**

Economic analysis

To assess the costs and benefits associated with different treatments, the partial budget technique of International Center for Maize and Wheat Research (CIMMYT) (1988) was applied. Total gross benefit was computed based on the average grain yield of maize and market price of the grains at the time of harvest. However, grain yield was adjusted downward by 10% to account for the effect of researcher-managed small plots as compared to the farmers managed plots as per the recommendation of CIMMYT (1988).Costs that vary (total variable cost) in the treatments include the fertilizers cost and labour cost for fertilizer application.The fertilizer prices were obtained from the official supply sources in the region (Enderta Union). The net benefit was computed by subtracting the total variable cost from the total gross benefit. The dominance analysis procedure as detailed in CIMMYT (1988) was used to select potentially profitable treatments from the range tested. The marginal rate of return (MMR) was obtained as a quotient of marginal increase in net benefit to marginal increase in cost and was calculated by considering a pair of non-dominated treatments listed in the order of increasing net benefit. As the combination of field management treatments tested in this study were new to the farmers, a minimum of 100% rate of return was assumed acceptable by farmers and any management practice with a return higher than this was considered worthy of investment (CIMMYT, 1988). All costs and benefits were calculated on hectare basis in Ethiopian Birr.

Results and Discussions

Effect on phenological growth

The ANOVA result revealed a significant difference ($p<0.05$) among method of fertilizer application and the different fertilizer rates on days to 75% flowering, silking and 90% physiological maturity but not on days to 75% tasseling (Table 1). Early flowering (104 days) was observed in the treatments with miscrodose application of 100% and 50% blended fertilizers and the longest flowering period was found in treatments of 10% blended fertilizer and 100% DAP and urea with the same application method, and 100% blended fertilizer with broadcast application and the control (106 days). As to silking, the result paint similar picture as that of the flowering where the shortest days were observed on microdosing of 100% and 50% blended fertilizer and the longest in the control treatment. The relative shorter days to flowering and silking observed in the aforementioned treatments could be attributed to the presence of macro and micro nutrients in the blended fertilizers and efficient utilization of the nutrients applied by microdosing. Efficient and sufficient nutrients result in rapid growth and hastened tasseling (Cock and Ellis 1992).

Table 1. Phenological growth stage of maize as affected by microdosing and fertilizer rates of blended fertilizer and Dap and urea

Treatment	Days to 75% Flowering	Days to 75% Silking	Days to 90% physiological maturity
Microdosing of 100% blended	104e	105e	141a
Microdosing of 25% blended	105d	108.3cd	139abc
Microdosing of 50% blended	104e	107de	140ab
Microdosing of 10% blended	106.3ab	110.7abc	137.3cd
Broadcasting of 100% blended	106.3ab	112.3ab	135d
Broadcasting of 100% DAP and Urea	106.3abc	112.7ab	135d
Microdosing of 100% DAP and Urea	105.3 bd	110bcd	139.3abc
Microdosing of 50% DAP and Urea	105.7abcd	110bcd	138.7ab
Microdosing of 25% DAP and Urea	106.7a	112.3ab	138bc
Microdosing of 10% DAP and Urea	105.7abcd	112.3ab	137cd
Control	106.3abc	113.7a	137cd
CV (%)	5	15	9

Where 100%= 100% of the recommended rate, 50%= 50% of the recommended rate, 25% = 25% of the recommended rate and 10%= 10% of the recommended rate. Treatments with the same letters aren't statistically significantly different.

Mean values of days to physiological maturity delayed by six days in microdosing of 100% blended fertilizer compared with broadcast application of the same fertilizer rate and by five days when the rate is reduced by half and applied in microdosing. Compared with the control treatment, the days to physiological maturity was delayed in three and four days in the treatments with microdosing of 50% and 100% blended fertilizer, respectively. However, the control treatment showed similar days to physiological maturity with the smallest rate (10%) of both fertilizers applied in either of the application methods (Table 1).

The delay in maturity in microdosing of 50% and 100% blended fertilizer could be attributed to the relaxed time of vigorousity growth at vegetative stage due to the presence of adequate fertilizers in the blended fertilizer. This result was in line with Brady and Weil (2002) who pointed out that abundant supply of nutrients promoted vegetative growth and delays maturity and with Akbar et al (2002) who reported that the maturity days of maize increased as fertilizer rate increased.

Effect on morphological growth

All the different rates of the two fertilizers applied in either of the application methods showed non-significant effect on plant height except in broadcasting of 100% DAP and urea and the control treatments (Table 2). Cop length of maize exhibited significant variation ($p \leq 0.05$) among the different treatments. On the other hand, the number of cops per plant was not affected neither by application method nor by rates of the fertilizer types. The highest plant height (174 cm) was measured in microdosing of 100% and 50% blended fertilizers that accounts 34.9% and 46% increment compared with the broadcasting of 100% DAP and urea, and the control treatments, respectively. This result was similar to that of Kubheka (2015) who found greater maize stalk height with the treatments that received a microdose of NPK fertilizer. Similarly, maximum cob length (19 cm) was recorded from microdosing of 100% blended fertilizer followed by microdosing of 50% and 100% DAP and urea (17 cm) and the lowest was measured in the control treatment (10 cm). The increment in plant height and cob lengths might be due to increase in cell elongation and more vegetative growth attributed to different nutrient content of blended fertilizer (NPKSZn).

Effect on yield and yield related traits

Dry aboveground biomass, grain yield and thousand seed weight were significantly affected ($p<0.01$) by the tested factors (Table 2). The highest dry aboveground biomass of maize (12.53 t ha^{-1}) was obtained by microdosing of the recommended rate of blended fertilizer (100%) followed by microdosing of 10%, 25% and 50% blended fertilizer and 100% DAP and urea. The increment was by 44.8% and 106% as compared to the control and broadcasting of DAP and urea at 100% rate, respectively While the lowest (4.7 t ha^{-1}) was recorded by broadcasting of blended fertilizer at a rate of 100%.

Thousand seed weight is an important indicator which directly affects the ultimate grain yield of a crop. The highest (0.45 kg) and lowest (0.28 kg) average thousand kernel weight were obtained from microdosing and broadcasting of 100% blended fertilizers, correspondingly. On the other hand non-significant difference was observed in treatments with microdosing of 25%, 50% and 100% of DAP and urea as well as microdosing of blended fertilizer at the rate of 10%, 25% and 50%. The more grain weight from microdosing of blended fertilizer might be attributed to positive interaction of nutrients in the blended fertilizers. The final weight of the grains is thus a result of the rate at which the kernel accumulates dry matter and the duration over which this occurs (Housely et al 1982).

Table 2. Morphological growth, yield and yield components of maize as affected by microdosing and fertilizer rates of blended fertilizer and DAP and Urea

Treatment	TSW (kg)	B (t ha^{-1})	PH	CL	GY (kg ha^{-1})
Microdosing of 100% blended	0.453a	12.53a	173.7a	19.33a	8415a
Microdosing of 25% blended	0.372b	11.17ab	169.3a	14.13def	7470ab
Microdosing of 50% blended	0.37b	11.53ab	174.3a	17abc	7867ab
Microdosing of 100% DAP and Urea	0.364bc	11.30ab	168.3a	17.4ab	7170ab
Microdosing of 50% DAP and Urea	0.358bc	10.89b	163.7a	15.53bcd	7037ab
Microdosing of 10% blended	0.348bc	11.19ab	163a	13.8def	6456ab
Microdosing of 25% DAP and Urea	0.342bcd	10.71bc	156.8a	14.5cde	7070ab
Control	0.33cd	8.65d	119.3c	10.03def	5978b
Broadcasting of 100% DAP and Urea	0.308de	6.08e	128.8b	12.2ef	4204c
Microdosing of 10% DAP and Urea	0.283e	9.45cd	160a	14.07def	6448ab
Broadcasting of 100% blended	0.277e	4.71f	154.7a	11.33f	3007c
CV (%)	6	16	8	10.1	15.8

Where TSW= thousand seed weight, B=Dry aboveground biomass, PH=plant height, CL=cob length, GY=grain yield

Yield, which is the marketable harvested product of maize was highest (8.4 t ha^{-1}) in the treatment that received 100% blended fertilizer applied by microdosing, while significantly lowest grain yields (3.0 t ha^{-1}) was obtained by broadcasting of 100% blended fertilizer. Mean grain yield by microdosing of blended fertilizer at a rate of 100% significantly increased by 100% and 40.8%, respectively, as compared with broadcasting of the recommended rate of DAP and urea (100 kg $^{-1}$) and control (Table 2). The increase in grain yield could be attributed to beneficial influence of yield contributing characters (cob length and seed weight) and positive effect of nutrients found in the blended fertilizer. This result agrees with Ousman and Aune (2011) and Camara et al (2013) who both found that microdosing of fertilizers increases productivity and yields of maize. Similarly, Tabo et al. (2007) showed that the average grain yields of millet and sorghum were greater by 44 to 120% while the farmers' income increased by 52 to 134% when using hill application of fertilizer compared to the earlier recommended fertilizer application-broadcasting method (farmers' practice).

It is a known fact that a grain yield is an aggregate of total performance of various growth and yield components of a given crop and this was confirmed by the correlation analysis result that indicated the positive and significant correlation of the yield with days to physiological maturity, plant height, cob length, above ground biomass, number of cob per plant, number of seed per cob and thousand seed weights (data not shown). This indicates that these parameters are important determinants of grain yieldas compared to days to flowering and days to silking which were negatively and significantly correlated with the yield. This result is in line with the finding of Pearl (2012) who reported a significant correlation between grain yield and 1000 seed weight, days to maturity, cob aspects and cob length, ears per plant, plant height and shelling percentage of maize.

Economic return

As indicated in Table 3, the highest net benefit (33,788 ETB) was observed from microdosing of 100% blended fertilizer followed by microdosing of 50% blended fertilizer, which are two of the non-dominated treatments while the lowest net benefit was obtained from broadcasting of DAP and urea at 100% rate. This indicated that blended fertilizers do have better benefit than the urea and DAP if they are applied by microdosing. Tabo et al (2007) also reported similar result who indicated that microdosing of fertilizers increased yields by 44% to 120% and farmers' income by 52% to 134% compared to traditional application methods. Similarly, research results in Mali and Sudan by Aune and Bationo (2008) indicated microdosing as an effective fertilizer application method for sorghum, maize and pearl millet production.

In the dominance analysis, seven of the treatments were dominated due to less net return at higher cost. Thus, the marginal rate of return (MRR) was computed from the remaining four non-dominated treatments namely control, microdosing of 25%, 50% and 100% of blended fertilizers (Table 4). The MRR shows how net benefit from a unit investment increases as the amount invested increases. In the given experiment, changing of the practice from control (no fertilizer) to microdosing of 25% of the recommended rate of blended fertilizer returned 43.1% MRR, which is below the 100% minimum rate of return. While changing the rate of the blended fertilizer from 25% rate to 50% using the same application method (microdosing) returned 100.35% MRR which was above the minimum rate of return. However, the MRR was 92% when microdosing of 50% blended fertilizer was changed to 100% blended microdose which was also below the minimum rate of return (100%). This implies that microdosing of 50% blended fertilizer would be the best recommendation for farmers as a farmer can have an extra gain of 1.0035 Ethiopian birr while recovering the initial investment of one ETB in the system. According to Camara et al (2013) microdosing is a successful method of fertilizer application that increased the agricultural yields and household incomes. Similarly, research in Mali, Niger and Burkina Faso with experience in microdosing have also shown microdosing as more profitable, more efficient use of the input than other forms of application (Tabo et al 2007).

Table 3. Partial budget analysis for microdosing and the different rates of fertilizers on maize

Treatments	Average yield (kg ha^{-1})	Adjusted yield (kg ha^{-1})	Gross field benefits. (ETB ha^{-1})	Total variable cost (ETB ha^{-1})	Net Benefit (ETB ha^{-1})	Dominance
Control	5978	4782.4	43041.6	15813.3	27228.3	ND
Broadcasting of 100% DAP & urea	4204	3363.2	30268.8	18466.7	11802.1	D
Broadcasting of 100% blended	3007	2405.6	21650.4	18706.7	2943.73	D
Microdosing of 25% blended	7470	5976	53784	23320	30464	ND
Microdosing of 10% DAP & urea	6448	5158.4	46425.6	23453.3	22972.3	D
Microdosing of 10% blended	6456	5164.8	46483.2	23746.7	22736.5	D
Microdosing of 25% DAP & urea	7070	5656	50904	23973.3	26930.7	D
Microdosing of 50%DAP & urea	7037	5629.6	50666.4	24413.3	26253.1	D
Microdosing of 50% blended	7867	6293.6	56642.4	24746.7	31895.7	ND
Microdosing of 100%DAP & urea	7170	5736	51624	26480	25144	D
Microdosing of 100% blended	8415	6732	60588	26800	33788	ND

ND: Non dominated; D: Dominated

Table 4. Marginal Rate of Return (MRR) analysis for the non-dominated treatments

Treatments	Total Cost (ETB ha^{-1})	Net Benefit (ETB ha^{-1})	MRR (%)
Control	15813.3	27228.3	-----
Microdosing of 25% Blended	23320	30464	43.10473
Microdosing of 50% Blended	24746.7	31895.7	100.3547
Microdosing of 100% Blended	26800	33788	92.15616

Conclusions and Recommendations

The result of this study revealed that growth and yield performance of maize was significantly affected not only by the rates of the commonly used DAP and urea fertilizers and the newly introduced blended fertilizers but also by the method of application of these fertilizers. The use of blended fertilizer showed a significant variation in yield and yield components of maize as compared to DAP and urea due to the presence of other essential nutrients like K, S, Zn in addition to the N and P. However, these fertilizers would increase their efficiency if they are applied near to the roots of the crop by microdosing unlike the commonly used method of application called broadcasting. The result of this study also showed that microdosing of blended fertilizer has an economic benefit to the farmers as it reduces the cost of production mainly the cost of the fertilizer. In this study, it was found that microdosing of the blended fertilizer reduced the rate by half and minimized the cost of production and as a result returned higher marginal rate of return. From this experiment, we recommend that using blended fertilizer that contain both macro and micro nutrients and applied to the right place by microdosing is not an alternative rather is a compulsory since the soil fertility problem in the region cannot be solved by applying a single nutrient containing fertilizer. Further research on more years and locations however is also recommended.

Acknowledgment

Our deepest gratitude goes to Climate Smart Agriculture in the Horn of Africa Project sponsored by Norwegian Agency for Development Cooperation (NORAD) for its all round financial support to conduct the study.

References

Akbar F Wahid A Akhtar S Ahmad AN and Chaudhary FM (2002): Optimization of method and time of nitrogen application for increased nitrogen use efficiency and yield in maize. *Pakistan Journal of Botany*, (31): 337-341.

Aune JB and Bationo A 2008. Agricultural intensification in the Sahel – The ladder approach. *Agricultural Systems*, (98):119-125

Berhane Guush, Paulos Zelekawork, Tafere Kibrom and Tamru Seneshaw (2011): Food grain consumption and calorie intake patterns in Ethiopia. Ethiopia strategy support program II, Ethiopia paper no. 23.

BoARD (Bureau of Agriculture and Rural Development) (2015): Annual Report. Bureau of Agriculture and Rural Development of Tigray, Mekelle, Ethiopia

Brady NC and Weil RR (2002): The Nature and Properties of Soils. 13th Ed. Prentice Hall, New Jersey, USA.

Camara B Camara F Berthe A and Oswald A (2013): Microdosing of Ceccotti SP Plant Nutrient sulfur: a review of nutrient balance environmental impact and fertilizers, Fertilizer research.

Cock RL and Ellis BG (1992): Soil management, a world view of conservation Krieger PublishingCompany, Malabar, Florida. 413 pp.

CSA (Central statistics Agency) (2018): Agricultural Sample survey 2017/2018, Report on Area and production of major crops (private peasantholdings, *Meher* season, Statistical bulletin vol. I. No 586.

International Center for Maize and Wheat Research (CIMMYT) (1988): From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Mexico, D.F.

EARO (Ethiopian Agricultural Research Organization) (2004): National crop research strategy EARO, Addis Ababa, Ethiopia

Hayashi T Abdoulaye T Gerard B and Bationo A (2008): Evaluation of application timing in fertilizer micro-dosing technology on millet production in Niger, West Africa. *Nutrient Cycling in Agro ecosystems*, (80): 257-265.

Housely TL Kirleis A Ohm HW and Patherson FL (1982): Dry matter accumulation in soft Red winter wheat seeds. *Crop Science Journal*, 22: 290-294.

Huffnagel HP (1961): Agriculture in Ethiopia. FAO, Rome

Khalily M Moghaddam M Kanouni H and Asheri E (2010): Dissections of Drought Stress as a Grain Production Constraint of Maize in Iran. *Asian Journal of Crop Science*, (2): 60-69.

McCutcheon A (2007): Agriculture Notes –Bioethanol in victoria AG1314,1-3 state of victoria . Department of primary industries, Victoria ; Australia

MOA and ATA (Minisry of Agriculture and Agricultural Transformation Agency) (2014): Soil fertility status and fertilizer recommendation for Tigray regional state, Ethiopia, Ministry of Agriculture and Ethiopia Agricultural Transformation Agency, Addis Ababa, Ethiopia

Ousman A Aune JB (2011): Effect of seed priming and micro-dosing of fertilizer on groundnut, sesame and cowpea in western Sudan. *Experimental Agriculture*, (47): 431-443.

Payne RW Harding SA Murray DA Soutar DM Baird DB Glaser AI Welham SJ Gilmour AR Thompson R and Webster R (2011): *GenStat Release 14 Reference Manual*. Part 2 Directives. VSN International, Hemel Hempstead, UK.

Pearl K (2012): Evaluation of newly released maize varieties in Ghana for yield and stability under three nitrogen application rates in two agro-ecological zones. Msc Thesis. Kwame Nkrumah University of Science and Technology, Ghana. 1-87 pp.

Tabo R Bationo A Gerard B Ndjeunga J Marchal D Amadou B Annou G Sogodogo D Taonda JBS Has-sane O Maimouna K Diallo and Koala S (2007): Improving cereal productivity and farmers' income using a strategic application of fertilizers in West Africa. *In:* Bationo A Waswa B Kihara J and Kimetu J (eds), Advances in integrated soil fertility management in sub-Saharan Africa: Challenges and opportunities. Kluwer Publishers, The Netherlands, 201–208.

Wondesen T and Sheleme B (2011): Identification of Growth Limiting Nutrients in Alfisols: Soil Physicochemical Properties, Nutrient Concentrations and Biomass Yield of Maize. *American Journal Plant Nutrition Fertilizer Technology,* (1): 23-35

Evaluation of NPSZnB Fertilizer on Yield, Yield Component of Maize (*May Zea* L.) on Different Soil Types under Rain-Fed Condition in Laelay Adiyabo and Medebay Zana Woredas

Kinfe Tekulu*, Tsadik Tadele, Tewelde Berhe, Solomun Mebrhatom, Goitom Aregawi, Tarekegn Yibabe, Weldegebreal Gebrehiwot, Gebresemaeti Kahsu and Samrawit Mebrhatu

Tigray Agricultural Research Institute, Shire Soil Research Centre, P.O. Box 40, Shire, Ethiopia
*Correspondence: tekulukinfe@gmail.com

Abstract

Use of right types and amounts of fertilizers utilization based on definite limiting nutrients and crop requirement for a given crop is economic and judicious for sustainable crop production. Accordingly, the current study was conducted at Laelay Adyabo and Medebay Zana Woredas on farmers' fields, located at North Western Zone of Tigray region in the years of 2017 and 2018 to investigate the effects of NPSZnB fertilizer for maize yield production. Seven treatments used for the field experiments were without fertilizer, blanket recommended NP (64 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1}) and five NPSZnB fertilizer rates (150, 200, 250, 300 and 350 kg ha^{-1}). The treatments were laid out in Randomized Complete Block Design (RCBD) with three replications. The results of the study revealed that fertilizer rates showed significant differences ($P \leq 0.05$) on almost all the maize traits tested except in 50% days to tasseling, 50% days to silking and 90% days to maturity in Laelay Adyabo Woreda. However, in Medebay Zana Woreda, except 50% days to tasseling, 50% days to silking and 90% days to maturity, plant height and thousand seeds weight, the rest parameters [above ground biomass yield, stover yield grain yield and harvest index (HI)] were significantly affected. In both Laelay Adyabo and Medebay Zana Woredas, the highest grain yield of 3.20 and 2.97 t ha^{-1} was obtained, respectively from application of NPSZnB fertilizer at the rate of 300 kg ha^{-1}. To evaluate the feasibility of the treatments, partial budget analysis was conducted and accordingly the highest marginal rate of return (217.62%) was obtained from application of 150 kg NPSZnB ha^{-1}. Therefore, based on the partial budget analysis, application of 150 kg NPSZnB ha^{-1} can be recommended as profitable for the production of maize in both Woredas, Laelay Adyabo and Medebay Zana, on similar soil type with the experimental areas.

Keywords: Blended fertilizer, Maize, Grain yield, Stover yield

Introduction

Soil fertility depletion, shallow, high run-off and low infiltration capacity of the soil is the major constraint to sustainable agricultural production in Tigray. Declining soil fertility is particularly severe in Tigray because of high nutrient losses through soil erosion, and extremely low use of external nutrient inputs and extreme exhaustion of plant nutrients from the soil are the major factors limiting crop production in both rain-fed and irrigated farms in the different agro-ecological zones of Tigray (Mitiku 1996; Virgo and Munro 1978). Nutrient mining due to sub optimal fertilizer use coupled with agronomically unblended fertilizer uses have favored the emergence of multi nutrient deficiency in Ethiopian soils (Wassie and Shiferaw 2011; Wassie 2010; Asgelil et al 2007; Abiye et al 2003) which results in decline and stagnant crop productivity conditions encountered despite continued use the blanket recommendation. To avoid soil nutrient mining and low crop productivity key strategies were identified to help increase agricultural production and productivity in Growth and Transformation Program (GTP I) period with development of soil fertility mapping of the country's agricultural lands. Based on this soil fertility map of Tigray region was also developed in 2014 year and published by Ministry of Agriculture (MOA) and Ethiopian Agricultural Transformation Agency (ATA) (2014) as part of the strategy. The necessity to transform agricultural sector with respect to soil fertility requires application of proper amounts of blended fertilizers for different crops.

Blended fertilizers containing nitrogen (N), phosphorus (P), sulfur (S), boron (B), iron (Fe) and zinc (Zn) have been recommended to site specific nutrient deficiencies and thereby increase crop production and productivity. The major recently recommended blended fertilizers for Tigray region by MOA and ATA are NPS, NPSB, NPSZn, NPSZnB, NPSFeZn and NPSFeZnB. Though potassium (K) was part of the previous recommended blend fertilizer, recently it was suggested to be applied based on soil test result. Because K is major nutrient and the amount of K in the previous blend fertilizers might not be sufficient for crop requirement. Experimentations of blend fertilizers were carried out for the last few years in Tigray. However, in many of the study sites there was no significance difference among the different blend fertilizers as compared with the conventional N and P recommendation. The probable reason could be due to comparison of the blended fertilizers to each other.

Although the type of required blended fertilizers are identified for the region, optimum rates of the major recommended blended fertilizer types for different crops, agro ecologies and soil types is not yet determined for the region. Besides, verifying the soil fertility map for major crops grown in the region in different agro ecologies and on different soil types in Tigray is urgently needed to increase crop yields and to improve quality of major crops grown in the region. Therefore, the main objective of the study was to evaluate the effects of NPSZnB fertilizer rates on yield, yield component of maize on different soil types under rain-fed condition at Laelay Adyabo and Medebay Zana Woredas.

Materials and Methods

Area description

A field experiment was conducted for two consecutive years during 2017 and 2018 main cropping season under rain fed conditions in Laelay Adyabo and Medebay Zana Woredas, North western Zone of Tigray Regional State. The altitudes of the Woredas vary between1783 and 2093 meter above sea level for Laelay Adyabo and Medebay Zana, respectively. Cambisols and Vertisols are the dominant soil types in the Laelay Adyabo and Medebay Zana Woredas, respectively. In both Woredas, crop-dominated mixed crop-livestock farming system is practiced. Laelay Adyabo Woreda received annual rainfall of 563.5 and 975.7 mm during growing season of 2017 and 2018, respectively while Medebay Zana Woreda received annual rainfall of 1013 and 1208 mm during growing season of 2017 and 2018, respectively (Figure 2). The rainfall distribution of these Woredas is a mono-modal with an erratic distribution. Laelay Adyabo Woreda had 31.4 and 12.1^{o}c , respectively maximum and minimum monthly temperature during 2017 and 31.6 and 11.9^{o}c maximum and minimum monthly temperature, respectively during 2018 (Figure 3) whereas Medebay Zana Woreda had 27.5 and 9.4^{o}c maximum and minimum monthly temperature of, respectively during 2017 and had 26.4 and 9.3^{o}c. maximum and minimum monthly temperature of, respectively during 2018 (Figure 3). Both study areas are found in a semiarid climatic zone.

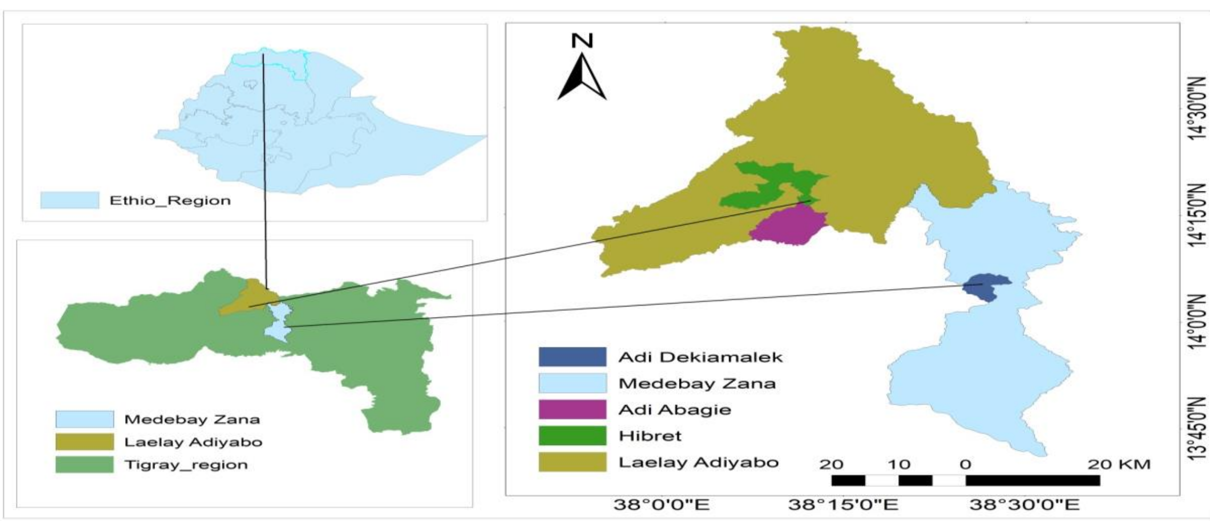

Figure 1. Location of the study area showing Ethiopia, Tigray region, Laelay Adiyabo and Medebay Zana Woredas and specific experimental sites of Adi Abagie and Hibret

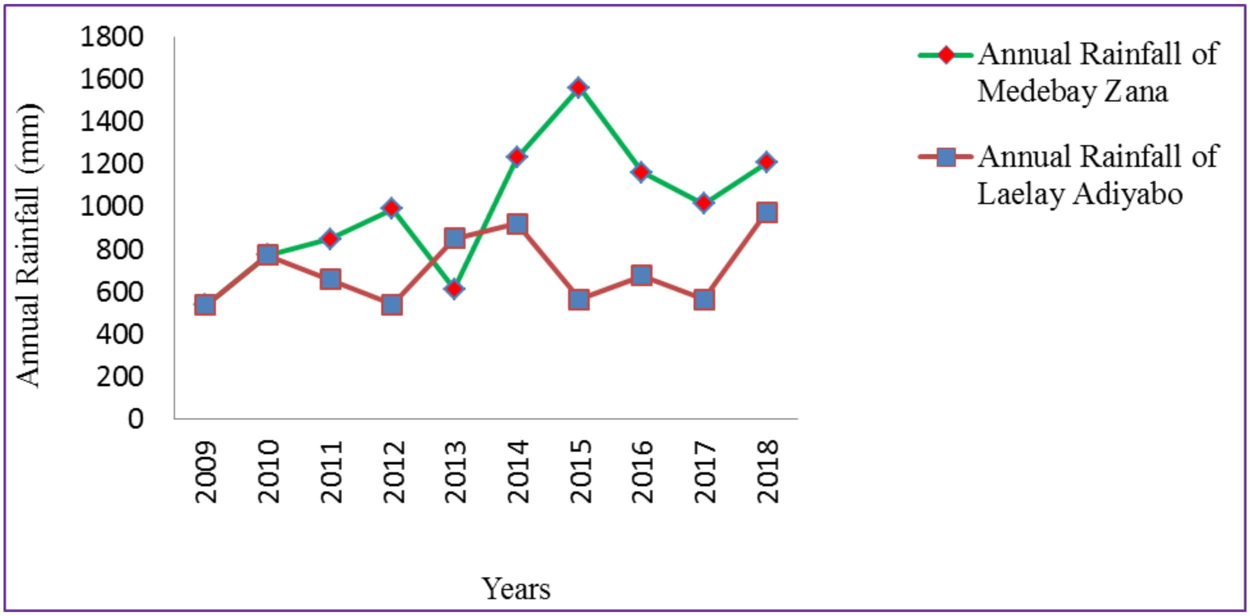

Figure 2. Ten years (2011-2018) annual rainfall measured in Laelay Adyabo and Medebay Zana Woredas

Experimental design and treatment

The experiments were laid out in RCBD in three replications each replicated four times and two times in different Tabias across farmers in Laelay Adyabo and Medebay Zana, respectively. The experiments had seven treatments [0, 150, 200, 250, 300 and 350 kg NPKSZnB ha^{-1} and recommended NP]. Sixty four kg ha^{-1} adjusted N was used for all treatments except control and recommended NP treatments. The rate of blanket recommended NP fertilizers were 64 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1}. Urea was used as source of N and triple super phosphate (TSP) was used as source P_2O_5 for the treatment of NP fertilizers. Blended fertilizers and half of N were initially applied at planting while the rest N was top dressed 45 days after planting. The test crop was also planted in rows with 75 and 40 cm spacing between rows, and plants, respectively. Plot size was 3.75 m by 4 m and net harvested plot area was 9.375 m^2 .Recommended seed rate of 30 kg ha^{-1} was used. All recommended crop management practices were applied.

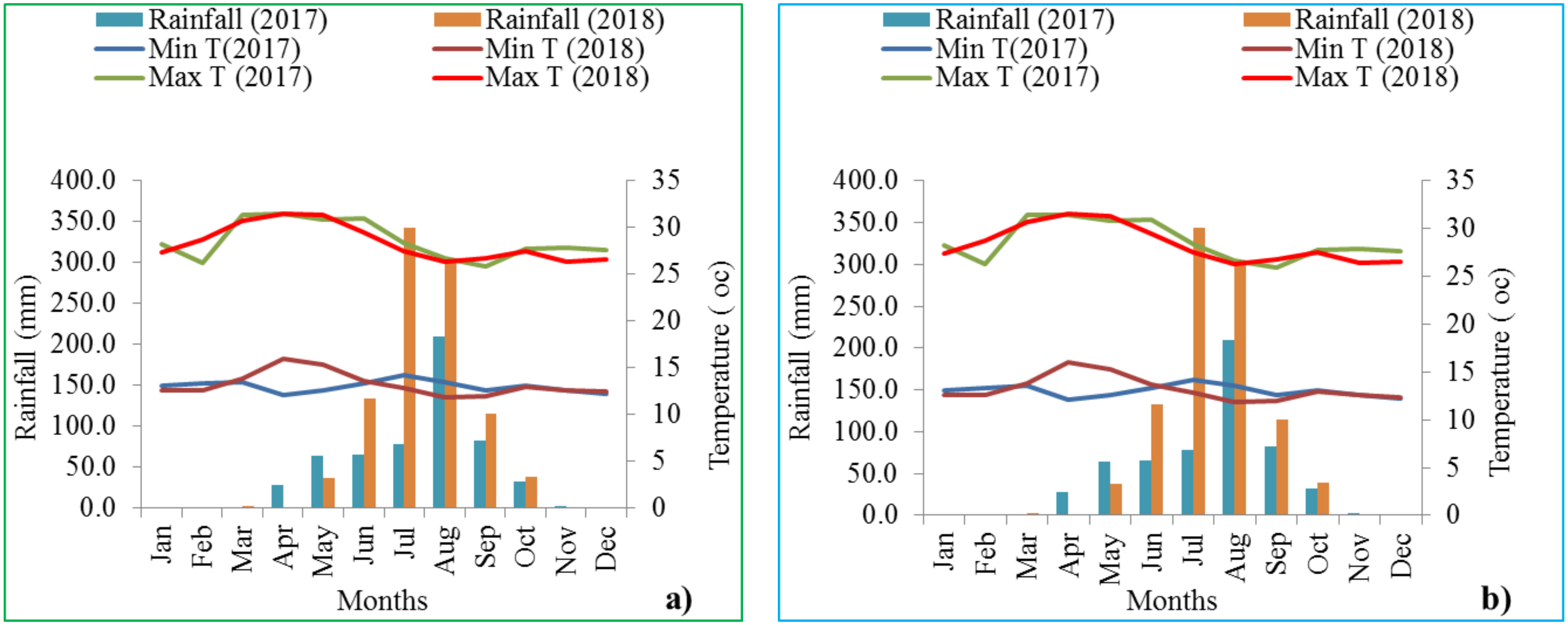

Figure 3. Monthly rainfall, maximum and minimum temperatures recorded in Laelay Adyabo (a) and Medebay Zana (b) Woredas during experimental years of 2017 and 2018.

Soil sampling and analysis

Before planting, surface composite soil samples were collected from each experimental site for site characterization and the soil samples were taken at a depth of 0-20 cm using auger for collecting the disturbed samples. The collected samples were properly labeled, packed and transported to Shire Soil Research Center and prepared for analysis according to the standard procedures.

Soil texture was determined using the Bouyoucos hydrometer method (Bouyoucos 1962). The pH of the soil was measured in the supernatant suspension of 1: 2.5 soil to water ratio using a pH meter (Rhoades 1982). Eelectrical conductivity (EC) was measured at 1:2.5 soil to water suspension according to the method described by (Jakson 1967). Organic carbon (OC) was determined by the method adescribed by Walkely and Black (1934). Available P (mg kg^{-1}) was analyzed by employing the Olsen method (Olsen et al 1954) using ascorbic acid as the reducing agent. Total N was measured using Kjedahl method as described by (Bremner and Mulvaney 1982). Cation exchange capacity (CEC) in cmol (+) kg^{-1} soil was determined by ammonium acetate method.

Table 1. Physico-chemical properties of soils of Laelay Adyabo experimental site before sowing

Parameters	Experimental sites							
	Site 1	Site 2	Site 3	Site 4	Site 1	Site 2	Site 3	Site 4
	Year one				Year two			
pH_{water} (1:2.5)	5.41	5.00	5.23	5.37	6.04	5.70	5.00	6.05
EC (mmh)	0.68	0.12	0.24	0.14	0.54	0.34	0.61	0.43
Ava. P (ppm)	21.04	4.23	23.24	15.45	17.00	20.00	12.00	24.00
% OM	3.11	1.20	2.50	1.50	2.76	3.00	1.56	3.45
TN (%)	0.13	0.06	0.14	0.08	0.15	0.16	0.09	0.19
CEC	30.20	21.20	63.21	61.46	45.00	57.00	20.43	56.00
% Sand	40.00	53.00	18.00	23.00	46.00	37.00	53.00	43.00
% Silt	43.00	44.00	33.00	33.00	53.00	33.00	35.00	22.00
% Clay	17.00	23.00	49.00	44.00	12.00	30.00	12.00	35.00
Tex. Class	loam	Sandy clay loam	Clay	Clay	loam	clay loam	sandy loam	Clay loam

Where, pH-power of Hydrogen, EC-Electrical Conductivity, OC-Organic Carbon, OM-Organic Matter, TN-Total Nitrogen, Av.P-Available Phosphorus, CEC-Cation Exchange Capacity, Tex-texture

Data collection

Data were collected on growth, yield and yield component related parameters on plot basis. Data such as days to 50% teaseling, days to 50% silking, days to 90% maturity, plant height (cm), biomass yield (kg ha^{-1}), stover yield (kg ha^{-1}), thousand seeds weight (g), grain yield (kg ha^{-1}) and harvest index (HI) were measured and calculated.

Table 2. Physico-chemical properties of soils of Medebay Zana experimental site before sowing

Parameters	Experimental sites			
	Site 1	Site 2	Site 1	Site 2
	2017		2018	
pH_{water} (1:2.5)	6.13	6.83	6.02	5.43
EC (mmh)	0.111	0.191	0.333	0.188
Ava. P	8.675	3.855	17.108	4.659
% OC	0.511	0.623	0.702	1.157
TN (%)	0.051	0.056	0.035	0.058
CEC	47.	46.5	40.00	31.40
% Sand	44	34	40	29
% Silt	44	30	40	22
% Clay	18	36	20	49
Tex. Class	loam	Clay loam	loam	Clay

Where, pH-power of Hydrogen, EC-Electrical Conductivity, OC-Organic Carbon, OM-Organic Matter, TN-Total Nitrogen, Av.P-Available Phosphorus, CEC-Cation Exchange Capacity, Tex-texture

Data analysis

The data were subjected to statistical analysis of variance (ANOVA) using SAS version 9.0 (SAS 2002). Significance differences among treatments means were assessed using the least significance difference (LSD) at 0.05 level of probability (Gomez and Gomez 1984).

Partial budget analysis

To evaluate the feasibility of the different treatments, partial budget analysis technique of International Center for Maize and Wheat Research (CIMMYT) (1988) was applied to stover and grain yield results which revealed significance difference. The partial budget analysis was performed based on the field price of the crop. Based on the CIMMYT manuscript, it is expected that experimental yields are often higher than the yields that farmers could expect using the same treatments. Hence, in economic calculations, the grain yield has been adjusted 10% lower than the actual yield obtained from the experimental plots to make the representative yield at the farmers' fields (CIMMYT 1988). It also included all the costs that vary for each treatment.

Result and Discussion

Crop phenology and growth parameters

Crop phenology

In both study Woredas, tasseling, silking and maturity of maize crop were not significantly affected by application of blended fertilizer rates (Table 3). This is may be due to effect of fertilizers on tasseling, silking and maturity of a single variety is not significantly varied. It was known that blend fertilizers in different rates of N, P, S Zn and B might have encouraged early establishment, rapid growth and development of crop thus shorten the day to tasseling silking and maturity but the current result is in reverse of that. In opposite to the current study by Dagne (2016), silking days were found significantly higher with the application of blended fertilizer. Contrary to the current study by, Bakala (2018) reported that days to 50% silking, tasseling and maturity were significantly affected by application of blended fertilizer rates.

Table 3. Days to 50% tasseling, days to 50% silking, Days to 50% maturity and plant height of maize crop under effect of NPSZnB fertilizer rates

Treatments (kg ha^{-1})	Two years combined result							
	DT (days)	DS (days)	DM (days)	PH (cm)	DT (days)	DS (days)	DM (days)	PH (cm)
	Laelay Adyabo Woreda				Medebay Zana Woreda			
0	77.50	82.75	127.88	177.62^{B}	85.73	94.00	129.93	212.18
150 NPSZnB	75.70	79.71	127.33	207.18^{A}	82.40	89.53	129.27	221.12
200 NPSZnB	67.00	79.96	127.38	209.83^{A}	82.40	89.87	129.67	220.13
250 NPSZnB	75.80	79.92	127.42	215.10^{A}	82.13	89.07	129.00	225.00
300 NPSZnB	75.40	79.25	127.38	219.74^{A}	82.73	89.00	128.93	229.93
350 NPSZnB	75.80	80.25	127.83	215.32^{A}	81.87	88.93	129.13	222.68
64 N, 69 P_2O_5	75.90	80.54	127.58	200.29^{AB}	83.67	90.53	129.53	217.37
Mean	117.58	80.34	127.54	206.44	82.99	90.13	129.35	221.20
LSD (P≤0.05)	NS	NS	NS	23.82	NS	NS	NS	NS
CV (%)	11.64	13.90	7.49	20.24	17.71	18.01	6.28	14.22

Where, means followed by the same letters are not significantly different (P≤0.05) according to Fishery Test, DT-Days to 50% tasseling, DS-days to 50% silking, DM-Days to 50% maturity, PH- plant height, kg-kilogram, ha-hectare, cm-centimeter N-nitrogen, P-phosphorus, S-sulfur, Zn-zinc, B-boron, P_2O_5-di phosphorus penta oxide, LSD-least significance different, NS-non-significance and CV-coefficient of variation.

Growth parameters

Plant height of maize crop was significantly affected by the application of blended fertilizer rates in Laelay Adyabo Woreda but it was not significantly affected in Medebay Zana Woreda (Table 3). Here the shortest plant height was measured in the plot treated with no application of fertilizers. However, there was no significant difference among the plots treated with blended fertilizer rates (150, 200, 250, 300, and 350 kg ha^{-1}) and the blanket recommendation of N and P fertilizers in Laelay Adyabo Woreda. This increment in plant height might be due to increment in cell elongation and more vegetative growth attributed to different nutrient contents of NPSZnB blended fertilizer. However, which of the nutrients in the blended fertilizer caused the variation was not clear. On the other hand, shortest plant height in unfertilized plots might have been due to low soil fertility level in the study area. Plant growth and development may be retarded if any nutrient element is less than its critical value in the soil or not adequately balanced with fertilization. In orthodoxy with the results obtained from this study, plant growth and development may be retarded significantly if any of nutrient elements is less than its threshold value in the soil or not adequately balanced with other nutrient elements (Landon 1991). This result is similar to that of Dagne (2016), and Tekle and Wassie (2018) who found that application of blended fertilizers and blanket NP recommendation significantly increased plant height as compared to the control. Unlike this findings, Bakala (2018) found that blended fertilizers had significantly influenced plant height.

Yield and yield components

Biomass yield

Application of blended fertilizers to maize crop brought significance effect on total above ground biomass yield in all study sites of the Woredas. In Laelay Adyabo Woreda, the highest biomass yield was recorded from application of blended fertilizer at the rate of 300 kg ha^{-1}. However, in Laelay Adyabo Woreda, there were no significance differennces among the NPSZnB blended fertilizer rates of 150, 200, 250, 300 and 350 kg ha^{-1} on biomass yield. These rates had significantly higher yields as compared to the control plot and standard checks. However, in Medebay Zana Woreda, the highest biomass yield was recorded from fertilization of blended fertilizer at the rate of 250 kg ha^{-1}. In this Woreda, the result among the four positive levels of blended fertilizers (200, 250, 300 and 350 kg ha^{-1}) and the recommended NP fertilizers did not revealed significance difference, but, the only difference was over the 150 kg NPSZnB ha^{-1} and control treatment. The lowest yield was recorded from the untreated checks. However, in the study Woredas there was no increase of yield consistently among the blended fertilizer levels. The smallest biomass yield was measured from the unfertilized plots in all study areas. This could be due to N effect in all treatments adjusted to the same amount of 64 kg N ha^{-1} except in control treatment. It was known that plants required huge amount of N nutrient as compared to all essential nutrients. The low yield in unfertilized plots might have been due to reduced leaf area development resulting in smaller radiation interception and this result in low efficiency in the conversion of solar radiation to prepare their food during photosynthesis. The result of this experiment was in agreement with that of Sharma et al (2011) who stated that fertilization of macronutrients integrated with micronutrients gave highest biomass yield of crops might be due to the additional supply of nutrients.

Stover yield

Stover yield was significantly affected by the treatments in both Woredas (Table 4). In Laelay Adyabo Woreda significantly highest yield was obtained from fertilization of maize plots with 150 kg NPSZnB ha^{-1}. There were no significant differences among blended fertilizers in this Woreda. The lowest yields were obtained from the negative control and positive control (standard checks). In Medebay Zana, the highest yield was recorded from application of 250 kg NPSZnB ha^{-1} blended fertilizer. In this Woreda, there was no significance differences in stover yields among 200, 250, 300 and 350 kg ha^{-1} levels of NPSZnB and the recommended NP fertilizers. The smallest yield was recorded from the control treatment. However, in both Woredas, there was no consistent increment in stover yield among the blended fertilizer levels. This could be due to N effect because N was adjusted to the same amount of 64 kg N ha^{-1} in all treatments except in the control treatment. It was known that plants require huge amount of N nutrient as compared to all essential nutrients. The low yield in unfertilized plots might have been due to reduced leaf area development resulting in reduced radiation interception and, consequently, low efficiency in the conversion of solar radiation. Contrary to this finding, Tekle and Wassie (2018) found that straw of tef was found highest in blended fertilizers as compared to control treatment and blanket NP recommendation.

Thousand seed weight

In Laelay Adyabo, thousand seeds weight of maize crop was found significantly affected by blended fertilizer rates only as compared to the negative contro. However, in Medebay Zana it was found non-significant. The five levels of NPSZnB blended fertilizer (150, 200, 250, 300 and 350 kg ha^{-1}) didn't indicate significance variations on thousand seeds weight of maize among each other. The standard check was also in par with the the blended fertilizer rates. The result in Laelay Adyabo was similar with that of Dagne (2016) and Tekle and Wassie (2018) who found that application of blended fertilizer significantly increased thousand seeds weight as compared to the control.

Grain yield

The result indicated that grain yield of maize crop was significantly affected by blended fertilizer rates in Laelay Adyabo and Medebay Zana Woredas (Table 5). In Laelay Adyabo, plots without fertilizer had significantly lower yield as compared to the five blended fertilizer rates (150, 200, 250, 300, 350 kg ha^{-1}) and standard check. However, there was no significant variation among the four rates of NPSZnB rates (150, 200, 250, and 300 kg ha^{-1}). Accordingly the highest grain yield was obtained from application of 300 kg NPSZnB ha^{-1}. In Medebay Zana, significance highest yield was obtained from application of 300 kg NPSZnB ha^{-1} as compared to that of NPSZnB levels (200, 350 kg ha^{-1}), recommended NP fertilizes and the control treatment. In the two Woredas, the highest yield was obtained from 300 kg NPSZnB ha^{-1}. However, in both Woredas, there was no consistent increment of grain yield among the blended fertilizer levels. This could be due to equal N treatments since N was adjusted to the same amount of 64 kg N ha^{-1} in all treatments except in control treatment. It was known that plants require huge amount of N nutrient as compared to all essential nutrients.

Table 4**.** Biomass yield, straw yield and thousand seeds weight of maize crop under effect of NPSZnB fertilizer rates combined over years (2017/2018)

Treatment (kg ha^{-1})	BY (kg ha^{-1})	SY (kg ha^{-1})	TSW (g)	BY (kg ha^{-1})	SY (kg ha^{-1})	TSW (g)
	Laelay Adyabo Woreda			Medebay Zana Woreda		
0	8434.20^{C}	6339.60^{C}	210.48^{B}	9692.90^{C}	8171.50^{C}	198.39
150 NPSZnB	14146.70^{A}	11118.20^{A}	225.70^{AB}	12526.20^{B}	9759.20^{BC}	218.51
200 NPSZnB	12945.10^{A}	9948.10^{A}	233.37^{AB}	13783.20^{AB}	11214.80^{AB}	217.13
250 NPSZnB	12664.40^{AB}	9678.00^{AB}	229.61^{AB}	14554.80^{A}	11762.50^{A}	217.69
300 NPSZnB	12917.30^{A}	9863.30^{AB}	241.81^{A}	14280.10^{A}	11307.10^{AB}	224.99
350 NPSZnB	12835.20^{AB}	10016.50^{A}	239.25^{A}	13659.70^{AB}	11223.30^{AB}	213.35
64 N, 69 P_2O_5	11166.10^{B}	8426.10^{B}	223.46^{AB}	13059.40^{AB}	10352.60^{AB}	217.09
Mean	12158.42	9341.42	229.10	13079.48	10541.58	215.31
LSD ($P\leq0.05$)	1681.10	1510.80	24.57	1747.50	1642.80	NS
CV (%)	24.25	28.37	18.81	16.43	19.17	15.74

Where, means followed by the same letters are not significantly different ($P\leq0.05$), BY- biomass yield, SY- stover yield, TSW-thousand seeds weight, NS-non-significance, CV-coefficient of variance

These results were similar to the findings of Benti (1993) who stated that although adoption of new varieties especially maize hybrid is moving fast in Ethiopia, fertilizer management techniques need to supplement the existing potential of the varieties. This showed that low soil fertility is among the greatest constraints to maize production in Ethiopia (Kelsa et al 1992). The increment in grain yield could be attributed to nutrients in the blended fertilizer. The association of grain yield with thousand seeds weight observed in this study is in line with Khatun et al (1999) findings who concluded that increasing thousand seeds weight yield attribute was the most important component directly related to grain yield in maize. Similarly, Tekle and Wassie (2018) found that grain yield of tef was found highest in blended fertilizers as compared to control treatment and recommended NP fertilizers.

Table 5. Grain yield and harvest index of maize crop under effect of NPSZnB fertilizer rates combined over years (2017/2018)

Treatment (kg ha^{-1})	GY (kg ha^{-1})	HI (%)	GY (kg ha^{-1})	HI (%)
	Laelay Adyabo Woreda		Medebay Zana Woreda	
0	2058.40^{D}	24.52^{ABC}	1521.40^{D}	15.94^{E}
150 NPSZnB	3021.40^{AB}	22.08^{C}	2767.00^{AB}	22.34^{A}
200 NPSZnB	3034.50^{AB}	24.26^{ABC}	2568.40^{BC}	18.81^{CD}
250 NPSZnB	2945.40^{AB}	24.25^{ABC}	2792.30^{AB}	19.56^{BDC}
300 NPSZnB	3200.00^{A}	26.52^{A}	2973.00^{A}	21.25^{AB}
350 NPSZnB	2922.30^{B}	23.45^{BC}	2436.40^{C}	18.20^{DE}
64 N, 69 P_2O_5	2751.20^{C}	25.81^{AB}	2706.90^{B}	21.04^{ABC}
Mean	2847.60	24.41	1521.40^{D}	19.59
LSD ($P \leq 0.05$)	255.65	3.10	249.40	2.44
CV (%)	15.75	21.98	12.09	15.33

Where, means followed by the same letters are not significantly different ($P \leq 0.05$), GY- grain yield, HI-harvest index, CV-coefficient of variance

Harvest index

In Medebay Zana and Laelay Adyabo, results of the investigation revealed that application of blended fertilizer rates had brought significant effect on HI of maize crop. In Medebay Zana the highest HI was measured from application of 300 kg NPSZnB ha^{-1} as compared to that of 150 and 350 kg NPSZnB ha^{-1}. However, this was not significantly different from control treatment, standard check and NPSZnB fertilizer rates of 200 and 250 kg ha^{-1}. Like the current findings in Laelay Adyabo, Tekle and Wassie (2018) found that HI of tef was found highest in blended fertilizers. In the second Woreda HI was found significantly highest from application of NPSZnB blended fertilizer of 150 kg ha^{-1} as contrasted to control treatment and NPSZnB blended fertilizer levels (200, 250 and 350 kg ha^{-1}) but, it was significantly in par with 300 kg NPSZnB ha^{-1} and recommended NP fertilizers.

Partial budget analysis

As it is shown in table 6 and 7, the net farm benefit was calculated taking possible field variable costs and all benefits (stover and grain yield) for Laelay Adyabo and Medebay Zana Woredas. The maximum farm net benefit were 31941.05 and 26276.60 birr ha^{-1} at the application of 150 and 300 kg NPSZnB ha^{-1} for Laelay Adyabo and Medebay Zana, respectively. In both Woredas the partial budget analysis revealed that application of 150 kg NPSZnB ha^{-1} resulted highest MRR% with values of 400 and 418 for Laelay Adyabo and Medebay Zana, respectively. These values implied that with one birr cost it was attained 4 and 4.18 birr profit. Therefore, for both Woredas NPSZnB at a rate of 150 kg ha^{-1} is recommended.

Table 6. Partial budget analysis of stover and grain yield of maize under NPSZnB fertilizer rates for Laelay Adyabo Woreda

Treatments (kg ha^{-1})	TVC	SY	ADSY	GY	ADGY	TSGR	TGGR	TSGGR	NB	MRR (%)
0	0.00	6339.60	5705.64	1852.56	1862.64	2282.256	20584	22866.26	22866.26	
150 NPSZnB	2275.50	11118.20	10006.38	2719.26	2686.95	4002.552	30214	34216.55	31941.05	400
200 NPSZnB	3034.00	9948.10	8953.29	2731.05	2699.28	3581.316	30345	33926.32	30892.32	D
250 NPSZnB	3792.50	9678.00	8710.20	2666.70	2666.70	3484.08	29630	33114.08	29321.58	D
64 N, 69 P_2O_5	4524.80	8426.10	7583.49	2476.08	2469.42	3033.396	27512	30545.40	26020.60	D
300 NPSZnB	4551.00	9863.30	8876.97	2880	2783.61	3550.788	32000	35550.79	30999.79	D
350 NPSZnB	5309.50	10016.50	9014.85	2630.07	2600.91	3605.94	29223	32828.94	27519.44	D

Table **7.** Partial budget analysis of stover and grain yield of maize under NPSZnB fertilizer rates for Medebay Zana Woreda

Treatments (kg ha^{-1})	TVC	SY	ADSY	GY	ADGY	TSGR	TGGR	TSGGR	NB	MRR (%)
0	0.00	8171.50	7354.35	1521.40	1369.26	2941.74	13692.60	16634.30	16634.30	-
150 NPSZnB	2275.50	9759.20	8783.28	2767.00	2490.30	3513.31	24903.00	28416.30	26140.80	418.00
200 NPSZnB	3034.00	11214.80	10093.30	2568.40	2311.56	4037.33	23115.60	27152.90	24118.90	D
250 NPSZnB	3792.50	11762.50	10586.30	2792.30	2513.07	4234.50	25130.70	29365.20	25572.70	D
64 N, 69 P_2O_5	4524.80	10352.60	9317.34	2706.90	2436.21	3726.94	24362.10	28089.00	23564.20	D
300 NPSZnB	4551.00	11307.10	10176.40	2973.00	2675.70	4070.56	26757.00	30827.60	26276.60	6.00
350 NPSZnB	5309.50	11223.30	10101.00	2436.40	2192.76	4040.39	21927.60	25968.00	20658.50	D

Where, TVC=total variable cost, SY=stover yield, ADSY= adjusted stover yield, GY=grain yield, ADGY= adjusted grain yield, TSGR=total stover yield gross return, TGGR, =total grain yield gross return, TSGGR=total stover and grain yield gross return, NB=net benefit, MRR=marginal rate of return, TSP=18.55 birr/1kg, urea=12.52 birr/1kg, NPSZnB=15.17 birr/1kg, maize grain=10 birr/1kg, maize stover=0.4 birr /1kg

Conclusions and Recommendation

Blended fertilizers had brought significant difference in all parameters except in days to 50% tasseling, days to 50% silking and days to 90% maturity in Laelay Adyabo. However, in Medebay Zana days to 50% tasseling, days to 50% silking and days to 90% maturity, plant height and thousand seeds weight were found non-significance. In Laelay Adyabo application of blended fertilizer had significantly affected the plant height as compared to N and P supply and the control. The analysis of variance of treatment on 1000 kernels weight revealed significance difference among fertilizer rates and types. The fertilizer rates and types in both Woredas revealed significance difference on above ground biomass yield, grain yield, stover yield and harvest index. In both Woredas, maximum and minimum grain yields were recorded with application of 300 kg NPSZnB ha^{-1} and control treatment, respectively.

In Laelay Adyabo, the maximum maize stover (11118.2kg ha^{-1}) was recorded with fertilization of 150 kg NPSZnB ha^{-1}, whereas in Medebay Zana, the maximum stover yield was found from application of 250 kg ha^{-1}, but in both Woredas, the minimum stover yield was obtained from the control treatment. According to the partial budget analysis the highest marginal rate of return was attained from application of 150 kg NPSZnB ha^{-1} as the best rates recommended for maize production in Laelay Adyabo and Medebay Zana Woredas with similar soil types with that of the study areas. Therefore, NPSZnB fertilizer at a rate of 150 kg ha^{-1} could be recommended to improve maize (*Melkasa 6Q*) production. However, it was not possible to identify the type (s) of nutrient (s) in the blend that caused the differences. Further study should be carried out to identify the nutrien element (s) that caused the variation.

Acknowledgements

The authors are grateful to TARI (Tigray Agricultural Research Institute)` and AGP II (Agricultural Growth Program II) project for their providing financial support and for their great assistance during the implementation of this work.

References

Abiye Astatke, Tekalign Mamo, Peden D and Diedhiou M (2003): Participatory on-farm conservation tillage trial in Ethiopian highland vertisols: The impact of potassium application on crop yield. Experimental Agriculture 40:369-379.

Agricultural transformation agency (ATA), (2014): Soil fertility status and fertilizer recommendation atlas for Tigray Regional State, Ethiopia.

Asglil Dibabe, Taye Bekele and Yesuf A (2007): The status of micro-nutrients in Nitisols, Vertisols, Cambisols and Fluvisols in major maize, wheat, tef and citrus growing areas of Ethiopia. In: Proceedings of Agricultural Research Fund Research Projects Completion Workshop held on 1-2 February 2007 at EIAR, Addis Ababa, Ethiopia. pp 77-96.

Bakala Anbessa (2018): Soil characterization and response of maize (*Zea mays* L.) to application of blended fertilizer types and rates in Asossa Woreda, Western Ethiopia. MSc Thesis, Haramaya University, Ethiopia.

Benti Tolessa (1993): The need and objective of the 1st National maize workshop. *In: Proceedings of the 1st National Maize Workshop of Ethiopia*. 5-7 May, 1992, IAR and IMWIC, Addis Ababa, Ethiopia.

Bouyoucos J (1962): Hydrometer method improved for making particle size analysis of soil. *Agronomy Journals*, (54):464-465.

Bremner JM and Mulvaney CS (1982): Nitrogen -total. In: A. L., R.H. Miller and D. R. Keeney (Eds.). Methods of soil analysis. Part 2-Chemical and microbiological properties. *American Society of Agronomy. Madison, Wis*, 9 (2): 595-624.

Dagne Chimdessa (2016): Blended fertilizers effects on maize yield and yield components of Western Oromia, Ethiopia. *Agriculture, Forestry and Fisheries*. Vol. 5, 5 (151-162). doi: 10.11648/j.aff.20160505.13.

Gomez KA and Gomez AA (1984): Statistical Procedure for Agricultural Research 2nd ed. John Wily and Sons, New York, 146-184.

International Maize and Wheat Improvement Centre (CIMMYT) (1988):. From agronomic data to farmer recommendations: Economic training manual. Completely revised edition. CIMMYT, Mexico.

Jackson ML (1967): Soil chemical analysis. Practice Hall of India. New Delhi.

Kelsa Kena, Tadesse Yoannes and Tesfa Bogale (1992): Influence of fertilizer and its management practices on maize grain yields in major maize producing areas of Ethiopia. *In: proceedings of the first national maize work shop of Ethiopia*.IAR (Institute of Agricultural Research), Ethiopia.

Khatun FS, Begum A, Mothin S, Yasmin and Islam MR (1999): Correlation coefficient and path analysis of some maize hybrids. Bangladesh. *J. Botany:* 28 (1): 9-15.

Landon JR (1991): Booker Tropical soil manual, a hand book for soil survey and agricultural land evaluation in the tropics and subtropics. Longman, Booker. Pp.474.

Mitiku Haile (1996): Soil resources of Central Tigray: a case study of selected farms in 7weredas. In: AO Øyhus & G Gebru (eds), Rural exploratory studies in the central zone of Tigray, Northern Ethiopia. *Proceeding of a workshop*, pp 19-33. Noragric, Addis Ababa, Ethiopia

Olsen R Cole S Watanabe F and Dean L (1954): Estimation of available phosphorus in soils by extraction with sodium bicarbonate. United States Department of Agriculture Circ. 939.

Rhoades JD (1982): In Methods of soil analysis, Part 2. second edition (A.L. Page. Miller and D.R. Keeney, Eds.), American Society of Agronomy. Madison, USA.

Richards LA (Ed.). 1954. Diagnosis and improvement of saline and alkaline soils. USDA Handbook No. 60, Washington, DC.

Statistical Analysis System (SAS) (2002): SAS/STAT User's Guide, Version 9.0. SAS institute Inc., Cary, NC

Tekle Lombamo and Wassie Haile (2018): Response of tef (Eragrostis tef (Zucc.) Trotter) to blended fertilizers in Tembaro, Southern Ethiopia. *Journal of Biology, Agriculture and Healthcare.* Vol.8, 13 (34-39).

Virgo KJ and Munro RN (1978): Soil and erosion features of the central plateau region of Tigray, Ethiopia. Geoderma 20 (131-157).

Walkley A and Black IA (1934). An Examination of the Degtjareff Method for Determining Soil Organic Matter and Proposed Chromic Acid Titration Method. *Soil Science*, 37 (29-38).

Wassie Haile, Shiferaw Boke and Kelsa Kena (2010):. Integrated Soil Fertility management options for sustainable crop production: Review of Research Findings from Southern Regional State of Ethiopia. Pp 163-175. In: Improved natural Resources management Technologies for Food Security, Poverty education and Sustainable Development. Proceedings of the 10th Conference of the Ethiopian Society of Soil Science. 25-27 March 2009, EIAR, Addis Ababa, Ethiopia.

Wassie Haile and Shiferaw Boke (2011): Response of Irish Potato (Solanumtuberosum) to the Application of Potassium at Acidic Soils of Chencha, Southern Ethiopia. International Journal of Agricultural Biology 13 (595–598).

Evaluation of NPSB Blended Fertilizer on Quality, Yield, And Yield Component of Sorghum Under Rain-Fed Condition in Tselemti Woreda, North Western Zone Tigray

Tsadik Tadele*, Geberesemaeti Kahsu, Weldegebrelgebrehiwet, Tewolde Berhe, Kinfe Tekulu, Tarekegn Yibabie, Solomon Mebrahtom, Samrawit Mebrahtu and Goitom Aregawi

Shire Soil Research Center, Shire, Ethiopia
*Correspondence: tsadiktadele27@yahoo.com

Abstract

A study was conducted during 2017 and 2018 main cropping seasons to evaluate different levels of blended (NPSB) fertilizer on yield and yield component of sorghum at two Tabias (Serako and Sekota Slasie) of Tselemti Woreda. The experiment had eight treatments including six levels of blended (NPSB) fertilizer (50 kg NPSB ha^{-1}, 100 kg NPSB ha^{-1}, 150 kg NPSB ha^{-1}, 200 kg NPSB ha^{-1}, 250kg NPSB ha^{-1} and 300kg NPSB ha^{-1}) and control plots (no fertilizer application) and recommended NP (46 kg N and 46 kg P_2O_5). The treatments were arranged in randomized complete blockdesign (RCBD) with three replications. The result indicated that the application of different levels of blended (NPSB) fertilizer significantly affected days to 50% heading, head length, plant height, above ground biomass yield and grain yield. Thus, the highest grain yield (2519.5 kg ha^{-1}) was observed from plots that received 300kg NPSB ha^{-1} whereas the lowest grain yield (1688.4 kg ha^{-1}) was recorded from plots with no fertilizer application. To separate the economically feasible treatment for farmers, partial budget analysis was performed. Based on the partial budget analysis, the highest net benefit (24,943.05) was obtained from a treatment with 300 kg ha^{-1} NPSB with percentage marginal rate return of 115.5. This indicates additional earning advantage in percent of birr 115.5 over the advantage earning birr of the preceding treatments. Therefore, 300 kg ha^{-1} NPSB is economically profitable and is recommended for farmers in Tselemti Woreda and other areas with similar soil and agro-ecological conditions.

Key word: Blended fertilizers, sorghum, marginal rate of return, Tselemti

Introduction

Sorghum (Sorghum bicolor (L.) Moench) belongs to the family Poaceae which is the fifth most important world cereal, following wheat, maize, rice and barley. It is one of the most important cereal crops grown in arid and semi-arid parts of the world, evolved in semi-arid tropical Africa, India and China where it is still used as a major food grain (Taye, 2013). Sorghum, because of its drought resistance, is the crop of choice for dry regions and areas with unreliable rainfall (Taye 2013).

Sorghum is one of the major staple crops grown in the poorest and most food insecure regions of Ethiopia. The crop is typically produced under adverse conditions such as low input use and marginal lands. It is well adapted to a wide range of precipitation and temperature levels and is produced from sea level to above 2000m.a.s.l (Fetene 2011). Its drought tolerance and adaptation attributes have made it the favorite crop in drier and marginal areas. Ethiopia is often regarded as the center of domestication of sorghum because of the greatest genetic diversity in the country for both cultivated and wide forms (Fetene 2011). Ethiopia is the 7th most important producer of sorghum in the world, with a share of 5% world average annual production and the third largest Africa sorghum producers. Most of the sorghum is consumed domestically. Sorghum producers and rural populations are estimated to consume about 87% of the total sorghum production in Ethiopia (FAO 2014).

Soil fertility is considered to be the major bottleneck constraint in crop production in Ethiopia which is due to continuous cultivation of the soils without adequate replenishment for many years (FAO, 1999). The major plant nutrients are N and P that added to the soil in the form of Di-Ammonium phosphate (DAP) and urea fertilizer (Henry 1990). Application of urea and DAP fertilizers has been adapted through extension program in Ethiopia. The blanket recommendations are applied regardless of considering the physical and chemical properties of the soil as well without considering climatic condition and available nutrient present in the soil (Taye et al 2000).

Fertilizer usage is one instrument implemented as a means of raising production and income of farm and households. However, the extent to which fertilizers are used still differs considerably between various regions of the world. In Ethiopia, DAP and urea are the only chemical fertilizers for crop production with initial understanding that nitrogen (N) and phosphorus (P) are the major limiting nutrients of Ethiopian soils Ethiosis (2013). There are many studies to improve agricultural productivity using urea and DAP in Ethiopia. Plant growth and crop production require an adequate supply and balanced amounts of all nutrients but the use of urea and DAP totally neglected the use of micronutrients. Since deficiency of micronutrients is reported in tropical soils, the application of nutrient sources that reduce such deficiencies is necessary.

Balanced fertilizers containing N, P, potassium (K), sulfur (S), boron (B) and zinc (Zn) in blend form have been recommended to ameliorate site specific nutrient deficiencies and thereby increase land, water and labor productivity. The need for site-specific fertilizer prescriptions is increasingly apparent, however, fertilizer trials involving multi-nutrient blends that include micronutrients are rare in Ethiopian context. Although there is general perception that the new fertilizer blends are better than the traditional fertilizer recommendation (urea and DAP), their comparative advantages were not explicitly examined and understood under various production environment. Hence, this study was aimed to determine the optimum blended fertilizer rate

Materials and Methods

Description of the study area

The field experiment was conducted during 2017 and 2018 main cropping season under rain fed conditions at farmer's field in Tselemti Woreda, North West Zone of Tigray Regional State. Tselemti Woreda which is one of the six Woredas of the Northwestern Tigray, is located 13^0 55' 53'' N and 38^0 12' 19'' E (Figure1). The Woreda altitude varies between 1242 and 1410 meter above sea level. Vertisols were the dominant soil types in the study area. The area has mono modal rain fall distribution (Figure2) with the mean annual rainfall of 1249.9mm and maximum and minimum temperature of 32. °C and 18.6°C, respectively.

Experimental design, procedures and treatments

The experiments were conducted at four farmer's field and the experiment had eight treatments including control (no fertilizer application) and recommended NP (46 kg N ha^{-1}, 46 kg P_2O_5 ha^{-1}) and six levels of blended (NPSB) fertilizer (50kg NPSB ha^{-1}, 100kg NPSB ha^{-1}, 150kg NPSB ha^{-1}, 200kg NPSB ha^{-1}, 250kg NPSB ha^{-1}, and 300kg NPSB ha^{-1}). A full dose of blended fertilizer were applied at planting time close to seed, while N fertilizer was applied in split application, half at planting time and the rest was three weeks after planting. Dekeba was used as a test crop and source of the fertilizers for N, P and blended fertilizers were urea, triple super phosphate (TSP) and NPSB, respectively. The treatments were laid out in RCBD with three replications. The plot size was 3.75 m by 4 m (15m^2), the spacing between rows and plots were

75 cm and 1 m, respectively. All recommended cultural practices for the test crop were done as per the recommendation.

Table 1. Treatment set up of the experiment in kg ha^{-1}

T1	T2	T3	T4	T5	T6	T7	T8
Control	50	100	150	200	250	3000	Recommended NP

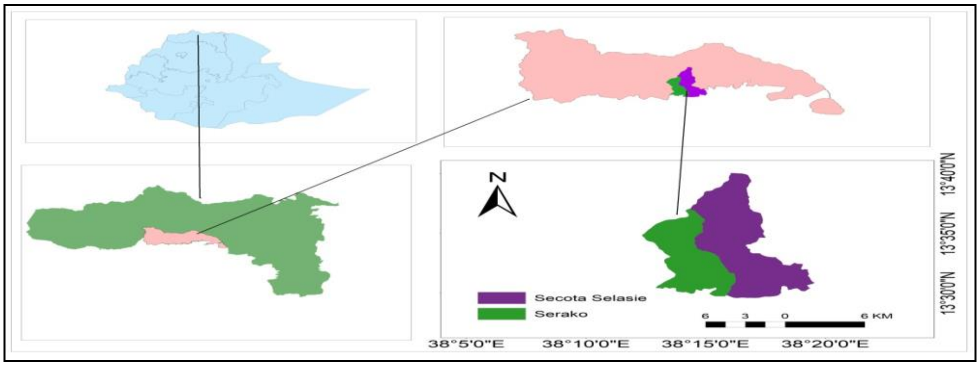

Figure 1. Location map of the study area at Tselemti Woreda north western Tigray, Ethiopia

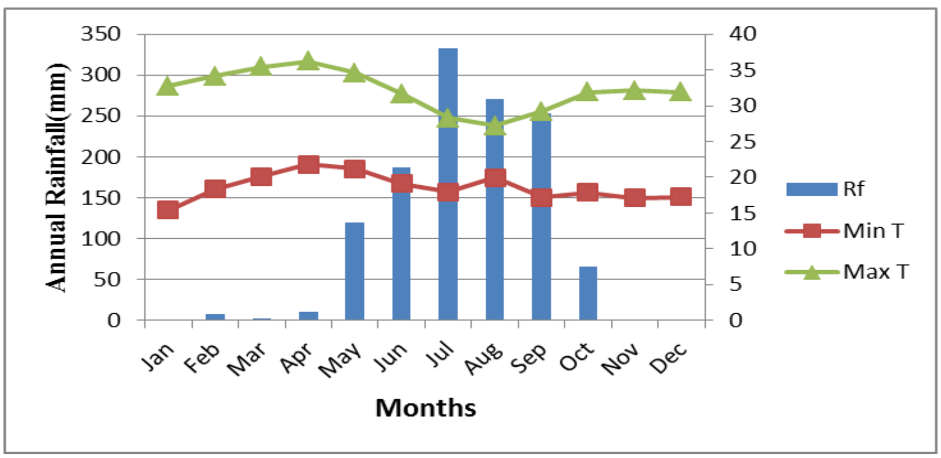

Figure 2. Rainfall, maximum and minimum temperatures recorded in the study area during the cropping season

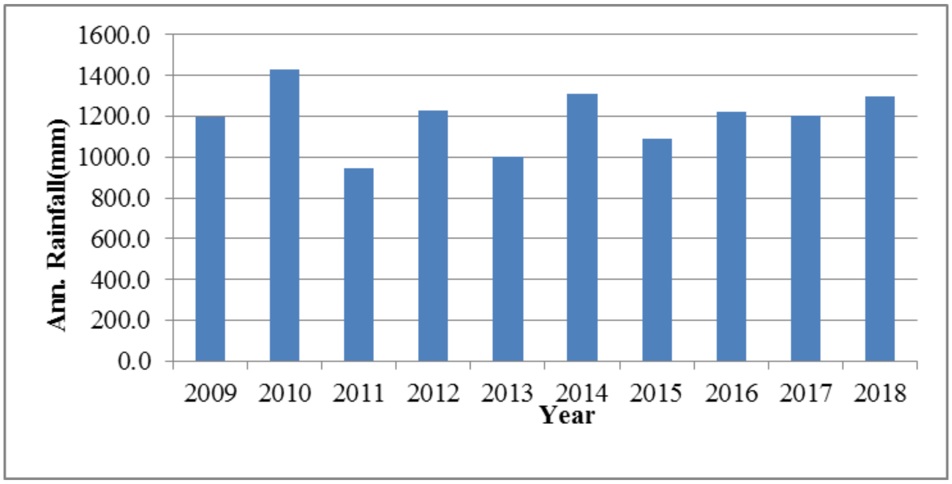

Figure 3. Ten years annual rainfall recorded in the study area

Soil sampling and analysis

Soil sampling

Pre planting, disturbed 15 sub samples (0-20cm) were collected using soil auger following diagonal sampling techniques within the experimental area and bulk in to one composite sample for physical and chemical analysis [soil reaction (pH), Electrical conductivity (EC), organic carbon (OC), organic matter (OM), (total nitrogen (TN), (available P (Av. P) and cation exchange capacity (CEC)] and after harvesting eight composite soil samples were collected from each experimental site. The collected soil samples were properly labeled, packed and transported to Shire Soil Research Center.

Soil analysis

All samples were analyzed following standard laboratory procedures as outlined by Sahlemedhin and Taye (2000). The pH and EC of the soil samples were measured in the supernatant suspension of 1: 2.5 soil to water ratio using a bench pH meter and EC meter, respectively. Organic carbon and total N of the soil were determined following the wet combustion method of walkley and Black (1934), and wet digestion procedure of Kjeldahl method (Bremner and Mulvaney 1982), respectively. The available P content of the soil was determined following Olsen method (Olsen et al., 1954). Soil texture was analyzed by Bouyoucos hydrometer method (Bouyoucos, 1962), (FAO, 2008). The CEC of the soil was determined following the 1N ammonium acetate (pH 7) method.

Physico-chemical properties of the soil samples before planting

Table 2. Pre sowing selected soil physicochemical property of surface soil samples (0-20cm) collected from the experimental sites

Soil Property	Site 1	Site 2	Site 3	Site 4
pH (H2O)	5.93	5.70	6.21	5.65
EC (ds/m)	0.110	0.172	0.252	0.210
Av. P (PPm)	5.600	6.71	3.74	6.86
% OC	1.352	1.320	0.966	1.20
% OM	2.331	2.276	1.665	2.069
% TN	0.117	0.114	0.083	0.103
CEC (meq per /100g soil)	41.51	46.75	58.40	41.00
% Sand	37	36	35	34
% Silt	45	47	47	45
% Clay	18	16	18	12
Textural Class	loam	loam	loam	loam

Agronomic data collection

Data on plant basis was recorded from the three central rows (6.75m2) out of the five rows per plot. The crop data collected were days to 50% heading, days to 90% physiological maturity, head length, plant height, stand count, total above ground biomass yield and grain yield and were subjected to statistical analysis using Statistical Analysis System (SAS) version 9.1 statistical software program (SAS 2004).

Result and Discussion

Effect of NPSB fertilizer on crop phenology of sorghum

Days to 50% heading and 90% physiological maturity

Analysis of variance revealed that the application of different fertilizer treatments significantly affected ($p < 0.05$) days to 50% heading (Table 3). However, the significant differences were only with the control (there were no statistically significant differences among the other treatments except with control).The maximum days to heading (89 days) were observed in control plots and the minimum days to heading (81days) were found in plants that received 300 kg NPSB ha^{-1}. The application of blended fertilizer (300kg NPSB ha-1) hastened by six days from recommended NP (46kg N and 46kg P2O5) and eight days from the control plots. This result is in agreement with that of Amare et al (2013) and Mebratu et al (2014) who reported that when the application rate of nitrogen fertilizer increased from 0 kg ha^{-1} to 150kg ha^{-1} there was a prolonged time required by the hot pepper to reach 50% flowering, 50% fruit set and 50% fruit maturity.

Application of the treatments did not significantly influence the treatments on days to 90 % physiological maturity (Table 3), but numerically there is a difference among the treatments. Hence, the longest days to 90% physiological maturity (124 days) was recorded in control plots and plots that received 200kg NPSB ha^{-1} and 250kg NPSB ha^{-1} matured 121days earlier than the other treatments.

Effect of NPSB fertilizer on crop growth parameters

The analysis of variance showed no significant differences among the treatments in head length, and plant height under the application of blended fertilizers (Table 4). However, the significant differences were only with the control (there were no statistically significant differences among the other treatments except with control) in plant height. There were no differences among plots treated with T1- T8 showing no signifecant difference between recommended NP and most of the NPSB rates in head length.

Table 3. Means of days to 50% heading and days to 90 % physiological maturity

Treatments	DH	DM
T1=control	88.97^{a}	123.96
T2= 50kg ha^{-1}NPSB	83.71^{b}	122.17
T3= 100kg ha^{-1}NPSB	82.79^{b}	121.71
T4= 150kg ha^{-1}NPSB	81.42^{b}	121.25
T5= 200kg ha^{-1}NPSB	81.63^{b}	121.08
T6= 250kg ha^{-1}NPSB	81.17^{b}	121.08
T7= 300kg ha^{-1}NPSB	80.92^{b}	121.21
T8= Rec. NP (100 and 100)	82.17^{b}	121.29
Mean	82.84	121.72
LSD	3.28	NS
CV	6.94	5.49

Where; DH = Days to 50% Heading, DM = Days to 90% physiological Maturity

The tallest (22.16cm) head length and plant height (145.383cm) were observed in plots that were treated with 300kg NPSB ha^{-1} and 150kg NPSB ha^{-1}, respectively while the shortest head length and plant height were found in unfertilized plots. The increment of head length might be due to increase in cell elongation and more vegetative growth attributed to different nutrient content of blended fertilizer. Gebrelibanos and Dereje (2015) reported that application of optimum amount of balanced fertilizer have significance variation on yield per panicle of sorghum. Contrary to this result, Dagne (2016) reported that a significant variation was obtained in plant height of maize due to the effect of blended fertilizer types.

Table 4. Means of Head Length, Plant Height and Stand Count

Treatments	Head length (cm)	Plant height (cm)
Control	19.1250[d]	138.292[b]
50 kg ha^{-1} NPSB	20.2750[c]	142.267[ab]
100 kg ha^{-1} NPSB	20.9083[bc]	142.342[ab]
150 kg ha^{-1} NPSB	21.75[ab]	145.383[a]
200 kg ha^{-1} NPSB	21.00[bc]	144.358[ab]
250 kg ha^{-1} NPSB	21.98[ab]	144.783[a]
300 kg ha^{-1} NPSB	22.16[a]	144.833[a]
Rec. NP (100 and 100)	21.30[abc]	141.775[ab]
Mean	21.06	143.004
LSD	1.10	6.11
CV	9.17	7.49

Yield and yield components of sorghum

Biomass yield and grain yield

The ANOVA result indicated that the application of different NPSB fertilizer rates affected the biomass yield of sorghum significantly at ($P< 0.05$) (Table 5). The highest biomass yield (8219.9 kg ha^{-1}) was found in plots that received 150kg ha^{-1} and the lowest biomass yield (6397.0kg ha^{-1}) was observed in control plots. However, there were no significant differences in biomass yield among plots treated with the NPSB fertilizer levels. Similar with this result Gebremeskel, (2017) reported highest biomass yield (12672 kg ha^{-1}) from the application of blended fertilizer amended with N and P which was statistically at par with the application of blended fertilizer NPKSZn. Related to this finding, Piri (2012) found that highest biological yield was obtained from treatment of 200 kg ha^{-1} of P and the lowest belonged to 50 kg ha^{-1} of P that showed increment of 77.16 percent in the biological yield of sorghum as compared with the 50 kg ha^{-1} P treatment.

Table 5. Means of biomass yield; grain yield and Harvest index

Treatments	Biomass yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index (%)
Control	6397.0[b]	1688.4[d]	28.64
50 kg ha^{-1}NPSB	7003.5[ab]	2053.5[c]	30.97
100 kg ha^{-1}NPSB	7322.9[ab]	2103.9[bc]	30.89
150 kg ha^{-1}NPSB	8219.9[a]	2266.4[abc]	30.18
200 kg ha^{-1}NPSB	7503.5[ab]	2156.5[bc]	30.33
250 kg ha^{-1}NPSB	7857.6[ab]	2380.9[ab]	31.53
300 kg ha^{-1}NPSB	7971.1[a]	2519.5[a]	33.20
Rec. NP (100 and 100)	6452.5[b]	1996.6[c]	32.63
Mean	7341.0	2145.7	31.1
LSD	1291.2	222.4	NS
CV	30.9	18.2	25.98

Application of different rates of NPSB fertilizer was statistically significant ($P < 0.05$) on the grain yield of sorghum (Table 5). Plants that were treated with 300 kg NPSB ha^{-1} showed significantly higher grain yield as compared to the recommended NP fertilizer and control plot. Thus, the lowest grain yield (1688.4 kg ha^{-1}) was found in plants with no fertilizer application and the highest (2519.5 kg ha^{-1}) was recorded in plants that treated with 300 kg NPSB ha^{-1}. Plots that were treated with 300 kg NPSB ha^{-1} had an increment in grain yield by 41.17% and 25.89% from the control plots and recommended NP fertilizer, respectively. Brhan (2012) also reported that high total yield was obtained from treatments that receive blended fertilizers compared with plots that receive DAP and urea and control plots in tef. In addition to this, Sujathamma et al (2015) found that application of high amount of blended fertilizer resulted in maximum grain yield of sorghum as compared with the small amount of blended fertilizers.

The ANOVA result showed that application of NPSB fertilizer did not significantly affect the harvest index (Table 5). However, numerically the highest (33.20) harvest index was found in plots that received 300 kg NPSB ha^{-1} and the lowest (28.64) was observed in control plots. The analyzed result also indicated that as the amount of NPSB fertilizer increase the harvest index of the crop also increased. This finding was similar with that of Birhanu (2012) who reported that plots that were treated with blended fertilizer had higher harvest index compared to unfertilized plots.

Partial budget analysis

To assess the costs and benefits associated with the different treatments, the partial budget technique of International Maize and Wheat Improvement Center (CIMMYT) (1988) was applied. According to this manual, experimental yields are often higher than the yields that farmers could expect using the same treatments; hence in economic calculations researchers have judged that farmers using the same technologies would obtain yields adjusted by 10% lower than those obtained by the researchers if the experiments are planted on representative farmers' fields, (CIMMYT 1988).

To separate the economically feasible treatment for farmers, partial budget analysis was performed. Based on the partial budget analysis, the highest net benefit (24,943 ETB) was obtained from a treatment with 300 kg ha^{-1} NPSB with percentage marginal rate return of 115%.

According to the manual for economic analysis of CIMMYT (1988) the recommendation is not necessarily based on the treatment with the highest marginal rate of return compared to that of neither next lowest cost, the treatment with the highest net benefit, and nor the treatment with the highest yield. The identification of a recommendation is based on a change from one treatment to another if the marginal rate of return of that change is greater than the minimum rate of return (100%). Thus, application of 300 kg ha^{-1}NPSB fertilizer rate with percentage of marginal rate of return (115.5) for sorghum grain yield was economically beneficial compared to the other blended fertilizer rates (Table 6).

Table 6. Partial budget analysis

Treatments	Fertilizer cost	Transport and labor cost	Total Variable cost	Adj. Grain yield	Total revenue	Net revenue	MRR (Ratio)	MRR (%)
00 kg ha-1NPSB	0	0	0	1,519.56	18,234.72	16,715.16	0.00	0
50kg ha-1NPSB	1980.25	140	2120.25	1,848.15	22,177.80	20,329.65	1.70	170
100kg ha-1NPSB	2708.85	210	2918.85	1,893.51	22,722.12	20,828.61	0.624	62.4
Rec. NP (100 and 100)	2918.75	210	3128.75	2,039.76	24,477.12	22,437.36	0.478	47.8
150kg ha-1NPSB	3437.45	280	3717.45	1,940.85	23,290.20	21,349.35	D	D
200kg ha-1NPSB	4166.05	350	4516.05	1796.94	21,563.28	19,766.34	D	D
250kg ha-1NPSB	4894.65	420	5314.65	2,142.81	25,713.72	23,570.91	1.0146	101.46
300kg ha-1NPSB	5623.25	490	6113.25	2,267.55	27,210.60	24,943.05	1.155	115.5

Adj. Grain yield = Adjusted grain yield MRR= marginal rate of return D= dominated

Conclusion and Recommendations

Application of different rates of blended fertilizer significantly ($p<0.05$) affected 50% days to heading. The lowest (80.9) days were observed from plants that were treated with 300 kg NPSB ha^{-1} followed by those plants that received 250 kg NPSB ha^{-1}which is (81.2 days). Head length, of sorghum was also statistically ($p<0.05$) affected due to the application of the blended fertilizer but there were no significant differences in plant height among the plots treated with fertilizers except with the control plot. The tallest (22.16cm) head length and plant height (145.383cm) were observed in plots that were treated with 300 kg NPSB ha^{-1} and 150 kg NPSB ha^{-1} respectively. Blended fertilizer application significantly ($p<0.05$) affected the above ground biomass of sorghum. The highest biomass (8219.9 kg ha^{-1}) was obtained from plots that were treated with 150 kg NPSB ha^{-1} followed by 7971.1kg ha^{-1} which was found from plants that received 300 kg NPSB ha^{-1}. Similarly, grain yield was significantly ($p<0.05$) affected through the application of the blended fertilizer. Therefore, higher grain (2519.5 kg ha^{-1}) was observed from plots that were treated with 300kg NPSB ha^{-1} followed by 1880.9 kg ha^{-1} from plants that received 250 kg NPSB ha^{-1}.

According the partial budget analysis, the highest net benefit (24,943.05) was obtained from plots treated with 300 kg ha^{-1} NPSB with percentage marginal rate return of 115.5. This indicates additional earning advantage in percent of birr 115.5 over the advantage earning birr of the preceding treatments. Therefore, 300 kg ha^{-1} NPSB is economically profitable and is recommended for farmers in Tselemti Woreda and other areas with similar soil and agro-ecological conditions.

Based on the results of the study, the following recommendations are forwarded.

- Impacts of the additional nutrients (S and B) in the blended fertilizer seem to significantly increased the biomass production of sorghum. Thus, further study across different locations is very important.
- Blended NPSB fertilizer at a rate of 300 kg ha^{-1} NPSB could be recommended for sorghum grown on Vertisols
- Additional studies are also needed on the impact of these blended fertilizers on straw and grain quality of sorghum.

Acknowledgements

The authors are grateful to TARI (Tigray Agricultural Research Institute)` and AGP II (Agricultural Growth Program II) project for their providing financial support and for their great assistance during the implementation of this work.

References

Amarew Tesfaw (2013): Performance of hot pepper (Cupsicom annuum) variety as inflounced by nitrogen and phosphorus fertilizers at bure. Upper watershed of blue nile in Northwestern of Ethiopia.

Birhanu Debele (1980): The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land use planning and regulatory department, ministry of agriculture, Adiss ababa, Ethiopia.

Bouyoucos J (1962): Hydrometer method improved for making particle size analysis of soil. Agronomy Journals. Vol 54:464-465

Bremner JM and Mulvaney CS (1982): Methods and soil analysis of total nitrogen part 2 Chemical and microbiological properties. Agronomy, 9 (2):595-624.

Brhan Abayu (2012): Agronomic and Economic Effects of Blended Fertilizers under Planting Method on Yield and Yield Components of Tef in Wereda Laelay maychew, Central Tigray, Ethiopia, unpublished M.Sc. thesis, College of Dry Land Agriculture and Natural Resources, Mekelle University, Mekelle , Ethiopia

Charman P and Rope M (2007): Soil Organic Matter. In P. Charman, B. Murphy (Eds.), Soils, their properties and Management (3rd Edition ed., pp. 276-285). Melbourne: Oxford University Press.

CIMMYT (International Maize and Wheat Improvement Centre) (1988):. From agronomic data to farmer recommendations: Economic training manual. Completely revised edition. CIMMYT, Mexico.

Dagne Chimdessa (2016): Blended Fertilizers Effects on Maize Yield and Yield Components of Western Oromia, Ethiopia. *Agriculture, Forestry and Fisheries*, 5(5): 151-162

Dagne Chimdessa (2016): Blended Fertilizers Effects on Maize Yield and Yield Components of Western Oromia, Ethiopia. Agriculture, Forestry and Fisheries, 5(5): 151-162

FAO (Food and Agriculture Organization) (2008): Guide to laboratory establishment for plant nutrient analysis, fertilizer and plant nutrition bulletin 19 Rome.

FAO (Food and Agriculture Organization) /WHO (World Health Organization) (2014): Value chain Study on Sorghum in Ethiopia

GebrelibanosG.and DerejeA (2015): Nitrogen fertilization effects on grain sorghum (S*orghum bicolor* L. Moench) yield, yield component and witch weed (*striga hermenthica (* Del.Benth) Infestation in Northern Ethiopia .*International Journal of Agricultural Research* 10(1):14-15

Gebremeskel Gebrekorkos (2017): Response of sorghum (Sorghum bicolor (L.) varieties to blended fertilizer on yield, yield and nutritional content under irrigation in raya valley southern zone of Tigray unpublished M.Sc. thesis, College of Dry Land Agriculture and Natural Resources, Mekelle University, Mekelle

Hazelto P and Murphy B (2007): Interpreting soil test results. What do all the numbers mean? 2nd Edition. CSIRO Publishing. 152p.
Jackson ML (1967): Soil chemical analysis. Practice Hall of India New Delhi.
Landon JR (1991): Booker Tropical soil manual: A handbook for soil survey and Agricultural Land Evaluation in the Tropics and subtropics. Longman and scientific Technical, Essex, New York. 474p
Mebratu A (2014): Effect of inorganic fertilizer on yield and physical quality parameter of a hot pepper (Cupsicom annuum) in South-Eastern Ethiopia.
Olsen R, Cole S, Watanabe F and Dean L (1954): Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *United States Department of Agriculture* Circ. 939.
Piri I (2012): Effect of phosphorus fertilizer and micronutrients foliar application on sorghum yield. *Annals of Biological Research* 3 (8):3998-4001
Rhoades JD (1982): In Methods of Soil Analysis, Part 2. Second Edition (A.L. Page Miller and D.R. Keeney, Eds.) American Society of Agronomy. Madison, USA.
Taye Bekele et al (2000): Soil fertility status and wheat nutrient content in Vertisol cropping systems of central highlands of Ethiopia
Tekalign Tadese (1991): Soil plant water fertilizer animal manure and compost analysis working document No 13. International Livestock research center for Africa, Addis ababa, Ethiopia.
Walkley A and Black IA (1934): An examination of the Degtjareff method for determining soil organic matter and proposed chromic acid titration method. Soil Science, 37:29-38.

Effect of Sowing Methods and Blended Fertilizer Rates on Yield and Yield Traits of Rain fed Upland Rice (*Oryza sativa* L.) in Tselemti, Ethiopia

Welegerima Gebrelibanos[1*], Alemtsehay Tsegay[2] and Addis Abrha[2]

[1]Tigray Agricultural Research Institute, Shire-Mytsebri Agricultural Research Center, P.O.Box 241, Shire, Ethiopia.
[2]Department of Dryland Crops and Horticulture Sciences, College of Dryland Agriculture and Natural Resource, Mekelle University, P.O.Box 231,Mekelle, Ethipia

Correspondence: welatg2002@gmail.com;

Abstract

Rice is recently introduced, produced and consumed in Tigray with the potential to contribute for food security. However, its productivity is limited mainly due to lack of improved varieties, poor agronomic practice and low soil fertility. Thus, study was initiated to determine an appropriate sowing method and blended fertilizer rate to improve rice productivity. A field experiment was conducted in 2017 cropping season at Tselemti Woreda with two factors: (i) three sowing methods (broadcast, dibbling and drilling); and (ii) five level of blended fertilizer rates NPSB (18.1, 38.1, 6.7, 0.71, (64, 46, 6.7, 0.71), (69, 60, 6.7, 0.71), (64, 46, 0, 0) and a control treatment. The experimental design was split plot with three replications where the sowing methods were used as main plots and the fertilizer rates as subplot. Composite soil samples were analyzed before sowing. Besides, data on crop phenology, growth, yield and yield components were collected and analyzed. The physicochemical properties of the study area is categorized as clay with low content of soil organic carbon, total nitrogen and available phosphorous. Sowing methods significantly affected plant height, panicle length, number of fertile tiller per panicle, thousand seed weight, biomass and grain yield. Blended fertilizer rate showed significant difference ($p<0.05$) on crop phenology, growth parameters, yield and yield components of rice. The interaction effect of fertilizer rate and sowing methods was significant on grain yield ($P \leq 0.001$), biomass and straw yield ($P \leq 0.01$). Maximum 5708 and 11496 kg ha^{-1} grain and biomass yield, respectively were obtained from the application of NPSB (69, 60, 6.7.0.71) kg ha^{-1} combined with dibbling method. The partial budget analysis revealed that the highest MRR 1698.3 and 1647.4 % were obtained from plots treated with NPSB (18.1, 38.1, 6.7, 0.71) and (64, 46, 6.7, 0.71) kg ha^{-1} under the dibbling sowing method, respectively. Based on the results it could be concluded that application of NPSB (64, 46, 6.7.0.71) kg ha^{-1} under the dibbling sowing method is better in terms of both biological and economical yield in the area.

Keywords: Blended fertilizer, Sowing method, upland rice, Marginal rate of return

Introduction

Rice has become a commodity of strategic significance and rapidly growing source of food across many African countries (Hegde and Hegde 2013). The total milled rice grain production in sub suhran Africa increased from 2 million tons in 1961 to 16 million tons in 2009. About

80% of rice in Africa is produced by small–scale farmers for their own utilization and local market (Africa Rice Center, 2011).

Rice was introduced to Ethiopia in the 1970s and has been cultivated in small pockets of the country (Zenna et al 2008). Even though rice is not a traditional staple food in Ethiopia but its feeding system is rapidly adopted by the farmers and preparing different recipes from rice. Currently, Ethiopia is fast emerging as one of the rice-producing countries in sub-Saharan Africa [National Rice Research and Development Strategy of Ethiopia (RRDSE) 2010]. In Ethiopia, three rice ecosystems were identified, (1) Rain fed upland rice, (2) Rain fed lowland rice, (3) Irrigated lowland rice growing under full irrigation access [Ethiopian Institute of Agricultural Research (EIAR) 2011]. Having the different agro ecology the potential for rice production area in Ethiopia is estimated to be about 30 million ha; from this potential 5 million ha is highly suitable [Ministry of Agricuture and Rural Development (MoARD) 2010]. Despite its relatively recent history of cultivation, rice in Tigray is considered to be one of the strategic crops of the region in alleviating poverty mainly due to its better yield and versatile uses (Alem and Feten 2015).

Rice has got wider adoption by Ethiopian farmers due mainly to social, economical, and environmental perspectives (Alem and Feten 2015). However, the productivity and competitiveness of the crop under farmers' field conditions is low. The average regional and notional yield is about 2.8 and 2.9 t/ha, respectively [Cental Statistical Agency (CSA) 2016], which is much lower than the world's average rice yield of 4.54 t/ha [Food and Agriculture Organization (FAO) 2012]. Several factors are generally known as the major constraints in upland rice production in the country. However, inadequate nutrient management, poor agronomic practices, pre and post harvest handling are some of research and development gaps given priorities under the current situation of rice production in Ethiopia (Taddesse 2009). Fertilization, particularly of the macro-nutrients such as nitrogen, phosphorus and potassium are a major input in rice production and then affect rice yield and quality due to the micro-nutrients like zinc, boron and cupper are depleted from the soils of major crop producing area of the country [Ethiopian Soil Information System (EthioSIS) 2013].

Other important factors which affect the yield of rice are poor agronomic practice like broadcast sowing method as a major yield limiting factor due to high and uneven population distribution leads to high competition for sunlight, moisture and nutrients. Broadcast sowing method cause nutrient loss from the soil plant system through leaching, NH_3 volatilization, de-nitrification and immobilization thereby reduce both yields and nutrient use efficiency of the crops. Nutrient use efficiency in rice under broadcast sowing method is 30 to 50% (Savant and Stangel 1990) which is very low. Based on the Ethiopian soil information system analysis report, NPSB is among the fertilizer types recommended for Tselemti Wereda. More ever there is no a comprehensive study made so far to understand rice sowing method and about the new NPSB blended rate for rice in the study area. Thus, this calls to investigate appropriate sowing method and blended fertilizer rate in the potential rice production area of Tselemti Woreda.

Material and Methods

Description of the study area

The field experiment was conducted at the research station of Shire Maitsebri Agricultural Research Center located in Tselemtiy distinct (Figure 1). Tselemtiy Woreda is found in the North western part of Tigray region, located 400 km away from the capital city of Tigray Mekelle. It is situated at $38^{o}15'$ E longitude and $13^{o}48'$ N latitude. The research station lies at 13^{o} 05'N latitude and 30^{o} 08' E longitude and has an altitude of 1350 meter above sea level. Tselemti Woreda has an altitudnale range of 800 to 2,870 meter above sea level and its agro-ecological zone is hot to warm-moist lowlands (78.35%), cool-moist mid highlands (19 %) and (2.65%) cool highland. The average (10 years) annual rainfall of the area is 1254.89 mm with a mean maximum and minimum temperature of 33.87 and 17.68^{o} C, respectively. The total monthly rainfall in the area during the 2017 growing season of the crop was 1293.0 mm characterized by bimodal rainfall pattern. The mean maximum and minimum monthly temperature during the growing season were 36.5 and 15.54^{o} C, respectively.

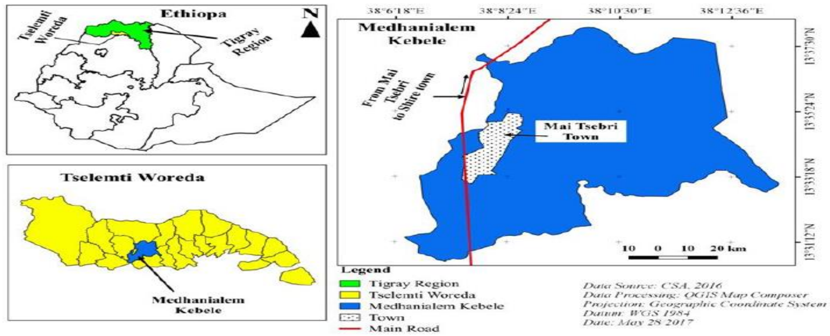

Figure 1. Location map of Tselemti wereda including the study area and Tigray region in Ethiopia (Source: Alem et al 2018).

Experimental design, treatments and procedures

The experimental design was split plot with three replications, where the sowing methods were used as main plot and blended fertilizer rates as a subplot (Table 1). The spacing between plot and blocks were 1 m and 1.5 m, respectively. Experimental plots were prepared 3 m by 2.4 m. Full dose of di-ammonium phosphate (DAP), NPSB and triple super phosphate (TSP) were applied at the time of planting, the combined nitrogen level found on both DAP and NPSB were used as a starter at the time of sowing and the full dose of Urea was side dressed at tillering and panicle initiation stage of the crop. Maitsebri 2, recently released rice variety with 80 kg ha^{-1} of seed rate was used for all sowing methods. All other cultural practices were applied uniformly to all plots as per standard recommendations for the crop. Sowing was done as per the on-set of the main growing season.

Table 1. Treatment Combinations used in the Experiment details are presented in table below

Trt	Treatment combinations
A. Main plot (type of sowing methods)	
	1. Broadcast Sowing Method
	2. Dibbling Sowing Method
	3. Drilling Sowing Method
B. Subplot (Blended fertilizer rate kg/ha)	
	1. Control it has (0N, 0P, 0S, 0B)
	2. 100 NPSB it has (18.1N, 38.1P, 6.7S, 0.71B)
	3. 100 DAP and 100 UREA it has (64N, 46P, 0S, 0B)
	4. 100NPSB+100UREA+17.4TSP it has (64N, 46P, 6.7S, 0.71B)
	5. 100NPSB+111UREA+48TSP it has (69N,60P,6.7S,0.71B)

Soil sampling and analysis procedure

Before planting one composite soil sample was collected from (0 - 20 cm) depth with an auger. Soil samples were air dried, crushed and passed through a 2 mm mesh sieve for physicochemical analysis. The collected soil before planting were subjected to texture, soil reaction (pH), organic carbon (OC), total nitrogen (N), available P, electric conductivity (EC) and cation exchange capacity (CEC) analysis. Soil texture was determined using the Bouyoucos hydrometer method (Bouyoucos 1962). The pH of the soil was measured in the supernatant suspension of a 1: 2.5 soil to water ratio using a pH meter by potentiometer method (Rhoades 1982). Available P was determined by Olsen et al (1954) method. Total N was determined using Kjedahl method as described by Bremner and Mulvaney (1982). Ammonium acetate method was used to determine CEC as described by Black et al (1965). Electrical conductivity meter was used to measure EC in 1:5 soils to water saturation extract referenced to a standard temperature of 25^{o}C (Jackson 1967). Organic carbon was based on the Walkley-Black chromic acid wet oxidation method by titrating with ferrous sulfate solution, using diphenylamine indicator to detect the appearance of unoxidized ferrous iron (Walkley and Black 1934).

Result and Discussion

Soil physical properties of the study site

The physical analysis results of the composite soil sample collected from the experimental area before sowing is presented in (Table 2). The proportion of the soil particle was found to be 34 % sand, 48 % clay and 18 % silt. Accordingly the soil textural class classified as clay.

Table 2: Chemical and physical properties of soil in the experimental site before sowing

Soil characters	Values	Rating	Reference
Sand (%)	34		
Silt (%)	18		
Clay (%)	48		
Texture Class	Clay		
pH	5.59	Moderately acidic	Horneck et al. (2011).
Organic carbon (%)	1.159	Deficient	Defoer et al. (2000).
Total nitrogen (%)	0.069	Low	Bashour (2007).
Available P (mg kg^{-1})	5.351	Low	Jones (2003).
EC (mmhos/cm)	0.45	Low	Marx et al. (1999).
CEC (cmol (+) kg^{-1})	53.1	High	Metson (1961).

Crop phenology and growth parameters

Days to panicle heading and maturity

Days to 50% panicle heading was significantly ($P < 0.001$) affected by the main effect of blended fertilizer rate (Table 3). Increasing rates of N and P in the amended blended fertilizer rate significantly affected days to 50 % panicle heading, while the main effect of sowing method andits interaction with blended fertilizer rates showed no significant effect. The highest mean number of days (90.6) to 50 % panicle heading was recorded from the control treatment followed by treatments that received lowest blended rate which is NPSB (18.1, 38.1, 6.7, and 0.71) kg ha^{-1} with a mean value of 79.2 days. The lowest 76.7 days to 50 % panicle heading was recorded from plots treated with the highest blended fertilizer which is NPSB (69, 60, 6.7, and 0.71) kg ha^{-1}. The results to 50 % panicle heading showed that increasing level of NP in the blended fertilizer rates had shorter days to panicle heading while decreasing level of N and P in the blended fertilizer rates delayed days to 50 % panicle heading. This might be attributed to high level of N and P fertilizer rate that enhanced the vegetative growth and hence reproductive stage of crop. In line with this result, Bahmanyar and Mashaee (2010) reported that rice plants that received no N and low N rates (N_0 and N_{50}) showed some N deficiency symptoms such as chlorosis, few numbers of tillers, delayed panicle heading and maturity.

Table 3. Mean of days to 50% heading (DH), days to 90% maturity (DM) as affected by sowing methods and blended fertilizer rates.

Trt. Combination	DH	DM
A. Sowing Methods		
(Broadcast)	80.47	107.4
(Dibbling)	80.00	107.2
(Drilling)	79.87	106.9
LSD (0.05)	2.418	1.3
P-Value	0.782	0. 543
B. Fertilizer rates kg ha^{-1}		
Control	90.67^{c}	112.7^{c}
NPSB (18.1, 38.1, 6.7, 0.7)	79.22^{b}	107.3^{b}
NPSB (64, 46, 6.7, 0.7)	76.89^{a}	105.4^{a}
NPSB (69, 60, 6.7, 0.7)	76.78^{a}	105.6a
NPSB (64,46, 0, 0)	77.00^{a}	104.8^{a}
LSD (0.05)	1.355	1.0
P-Value	<0.001	<0.001
CV (%)	1.3	0.5

Means with the same letter in a column are not significantly different, CV = Coefficient of Variation;

A statistically significant ($p<0.001$) difference was observed on days to 90% maturity due to the different blended fertilizer rates over the control and the lowest blended fertilizer rates (Table 3). Delayed physiological maturity was observed on control treatment with a mean value of 112.7 days, followed by the lowest blended rate NPSB (18.1, 38.1, 6.7, and 0.71) kg ha^{-1} with a mean value of 107 days. While, the shortest number of days to physiological maturity were recorded from the plot treated with blanket recommendation. From the analytical results it was observed that increasing N and P rates in the blended fertilizer rate triggerred quicker reproductive phase responses and vice versa. This finding is in line with Halima et al (2017) who reported that rice plants that received no N and low N rates (N_0 and N_{50}) kg ha^{-1} showed some N deficiency symptoms such as chlorosis, few numbers of tillers and finally delayed maturity.

Plant height and panicle length

Plant height

Both sowing methods and blended fertilizer rates significantly affected ($p<0.05$) the development of plant height. The highest plant height (79.6 cm) was recorded from the dibbling sowing method followed by drilling sowing method (75.68 cm) and the lowest plant height (71.72 cm) was recorded in the broadcast sowing method (Table 4). The variation in plant height could be due to plants sown at a specific distance leads to less competition for nutrients, space, light and moisture among the plants. This is in lines with the finding of Oyewole et al (2010) who reported that dibbling sowing methods had the highest establishment of plants than broadcasting and drilling sowing methods. Likewise, Awan et al (2007) also reported that the difference in plant height was due to better plant establishment and less competition among the plants in dibbling sowing methods. This also corresponds with the finding of Berhe et al (2011) on tef and planted by drilling method that resulted in taller plants than the broadcasted seed.

In the dibbling sowing method, the root penetration to the soil becomes high due to making a row with 2-3 cm depths at sowing and resulting in efficient nutrient uptake from the soil and minimizes nutrient loss easily soluble fertilizer such as urea through volatilization, run off and de-nitrification. The other possible reason could be that in dibbling and drilling sowing methods the loss of nutrients may be lower than broadcasting method as the fertilizers placed and covered side by side with the rice seed. Most of the yield reduction from urea left on the soil surface without incorporation in broadcast sowing method has been attributed to ammonia volatilization. This result supports the finding of Bautista et al (2000) who concluded that placement of any N source fertilizer with simultaneous soil cover was effective in minimizing its loss by flood water ammonium-N losses and ammonia volatilization.

Plant height was also significantly ($p<0.01$) affected by the different blended fertilizer rates. Plant height increased with increasing rates of N and P in the blended fertilizer rates. It is evident from Table 4 that, significantly higher mean plant height (81.47 cm) was found on treatments that received the higher level of blended fertilizer rates which was NPSB (69, 60, 6.7, 0.71) kg ha^{-1} and this blended fertilizer rate was amended by urea and TSP to increase N and P content from 18.1 and 38.1 to 69 and 60, respectively, followed by treatments fertilized with NPSB (64, 46, 6.7, 0.71) kg ha^{-1} having the average value of 80.2 cm, While the lowest 69.38 cm was recorded from the control NPSB (0, 0, 0, 0) kg ha^{-1}, followed by the lowest blended rate which was NPSB (18.1,38.1, 6.7, 0.71) kg ha^{-1} with the average value 69.9 cm. The promotion of rice plant height in the highest rates might be due to applications of NP is apparent as N is an essential nutrient for plant growth since it is a constituent of all proteins and nucleic acids, whereas P is essential for production and transfer of energy in plants. The result obtained from this study were in line with the finding of Dereje et al (2017) who found a significant increased rice plant height from 68.7 cm to 79.1 cm with application of 138 N kg ha^{-1}, when the level of N increased up to N 138 kg ha^{-1} significantly ($p< 0.001$).The same author also reported that the promotion of rice plant height was due to the fact that N is an essential nutrient for plant growth since it is constituent of all protein and nucleic acids.

Panicle length

Panicle length is one of the growth parameters in rice and was significantly affected by both sowing methods and blended fertilizer rates but not by their interaction (Table 4). The analysis of variance result showed that the taller panicle length was recorded from dibbling sowing method followed by drilling sowing method with a mean value of 19.63 cm and 18.68 cm, respectively where as the lowest 17.41 cm mean panicle length was recorded under the broad cast sowing methods. The difference in panicle length could be due to more space, sunlight and nutrients availability in dibbling and drilling sowing methods, whereas in broadcasting sowing method there was no specific space between the rows and the crops that increased competition of resources and that hindered the development of panicle length and other yield attributes. Similarly, panicle length was significantly ($p<0.001\%$) influenced by the different blended fertilizer rates (Table 4). The higher mean panicle length was obtained from NPSB (69, 60, 6.7, 0.71) kg ha^{-1} followed by NPSB (64, 46, 6.7, 0.71) kg ha^{-1} with a mean value of 20.04 cm and 19.44 cm, respectively. The shortest mean panicle length was recorded from the lowest blended fertilizer rate which was NPSB (18.1, 38.1, 6.7, and 0.71) kg ha^{-1} and the control with a mean value of 17.06 cm and 17.40 cm, respectively.

Table 4. Main effects of sowing methods and blended fertilizer rate on plant height and panicle length of rain fed upland rice.

Treatments	Phenological parameters	
A. Sowing Methods	Plant height (cm)	Panicle length (cm)
(Broadcast)	71.72^{c}	17.41^{b}
(Dibbling)	79.65^{a}	19.63^{a}
(Drilling)	75.68^{b}	18.68^{a}
LSD (0.05)	3.441	1.00
P- Value	<0. 008	<0. 009
B. Blended rate (kg ha^{-1})		
(Control)	69.38^{c}	17.40^{c}
NPSB (18.1, 38.1, 6.7, 0.7)	69.94^{c}	17.06^{c}
NPSB (64, 46, 6.7, 0.7)	80.2^{ab}	19.44^{ab}
NPSB (69, 60, 6.7, 0.7)	81.47^{a}	20.04^{a}
NPSB (64,46, 0, 0)	77.42^{b}	18.92^{b}
LSD (0.05)	3.416	0.95
P- Value	<0. 001	<0. 001
CV (%)	2.0	2.4

CV = Coefficient of Variation; Means in column followed by the same letters are not significantly different at 5% level of Significance

Yield and yield components

Number of fertile tillers per plant

The analysis of variance for the number of fertile tillers per plant revealed significant (P < 0.001) differences for the main effect of blended fertilizer rates and at 5% probability level for sowing methods among the treatments, although it was not influenced by their interactions. The highest (5.45) number of effective total tillers per plant was recorded in dibbling sowing method followed by the drilling sowing methods (4.1), while the lowest (3.16) was recorded from the broad cast sowing methods (Table 5). This might be attributed due to the low competition for resources in both dibbling and drilling sowing methods than broadcasting method. This finding is in line with Oyewole et al (2010) who reported that dibbling sowing method had the highest establishment of plants than the drilling and broad casting methods.

Likewise for the main effect of blended fertilizer rates the maximum number of fertile tillers per plant was 5.3 followed by 4.7 and were recorded from the highest rate of blended fertilizer NPSB (69, 60, 6.7, 0.71) kg ha^{-1} and NPSB (64, 46, 6.7, 0.71) kg ha^{-1}, respectively. While the lowest number of fertile tillers was obtained from the lowest blended rate and the control treatment with a mean value of 3.7 and 3.08, respectively. The reasons for that might be due to the application of different N and P nutrients which simulate vegetative growth, development and accelerate tillering capacity of the crop. In addition to this, P also reduces tiller sterility. The result is similat to that of Fairhurst et al (2007) who found increased number of fertile tillers, panicle length and number of spikelets which consequently increased grain yield in kg ha^{-1} by the application of N and P nutrients.

Number of fertile grain per panicle

The analysis of variance showed significant difference (P<0.01) in number of fertile grain per panicle due to the effects of different blended fertilizer rates and different sowing methods. However, their interaction effect was not significantly different (Table 5). With regard to the main effect of sowing methods, the highest number of fertile grains per panicle (100.12) were found from the dibbling sowing method followed by drilling method (86.92) and the lowest 7(9.55) number of fertile grain per panicle from the broadcast method (Table 5).The variation in the methods of planting could be due to better crop establishment or growth of rice plants as a result of lesser competition for water, sunlight and nutrients. This is similar to the report by International Rice Research Institute (2008) which stated that dibbling and line sowing methods enables optimal spacing, and can increase number of effective tillers, grain per panicle and finally paddy yield over poor spacing and/or broadcast methods.

There was an increasing trend in the number of fertile grain per panicle across the increasing rates of N and P_2O_5 in the blended fertilizer rates. The highest number of grains per panicle was recorded from the highest level of blended rate which is NPSB (69, 60, 6.7, 0.71) kg ha^{-1} followed by NPSB (64, 46, 6.7, 0.71) kg ha^{-1} with a mean value of 103.60 and 95.9, respectively. The lowest number of fertile grain per panicle was observed from the lowest blended fertilizer rate of NPSB (18.1, 38.1, 6.7, and 0.71) kg ha^{-1} and the control treatment with the mean value of 71.96 and 81.62, respectively. These results may have been influenced by the application of the additional NP from other sources of inorganic fertilizers. As described by Mattson et al (2009) increasing levels of ammonium and nitrate in the soil can facilitate plant growth and development and then increase the yield components of rice.

Thousand Seed weight

Analysis of variance on this parameter showed significant effect due to blended fertilizer rates (p<0.01) and sowing method (p<0.05), while the interaction effect of both factors did not show significance difference for thousand seed weight (Table 5). For the main effect of sowing methods, the highest thousand seed weight was recorded from the dibbling sowing method while the other two sowing methods did not show statistically significance difference among each other. This might be due to the wider spacing in dibbling sowing method that encouraged proper crop growth and development and assimilate synthesis in the grains.

The highest thousand seed weight (35.71 g) was recorded for treatments that received NPSB (64, 46, 6.7, 0.71) kg ha^{-1} blended fertilizer followed by NPSB (64, 46, 6.7, 0.71) with a mean value of 34.98 g, while the lowest (33.2 g) thousand seed weights were recorded from the control and the previously used rate in the area. The significance difference in thousand seed weight with the blended fertilizers might be due to the presence of substantial difference among treatments in the major NP nutrients which play the major role in growth and development of a crop and accelerate photosynthesis activity. This result is like that of the Fageria et al (2011) who indicated that use of organic and inorganic sources of plant nutrients significantly reduced grain sterility which were positively and directly associated with grain yield.

Table 5. The yield and yield parameters of rice under the main effect of sowing methods and blended fertilizer rates.

Treatments	Phenological parameters			
	FT_PP	FG_PP	TSW	HI
A. Sowing Methods				
(Broadcast)	3.160^c	79.55^b	33.88^b	0.46
(Dibbling)	5.453^a	100.12^a	34.97^a	0.48
(Drilling)	4.107^b	86.92^b	34.14^b	0.47
LSD (0.05)	0.8642	11.41	0.56	4.1
P-Value	< 0. 005	< 0. 018	< 0. 012	<0. 379
B. Fertilizer rates kg ha^{-1}				
NPSB (0, 0, 0, 0)	3.089^d	81.62^c	33.2^c	0.48
NPSB (18.1, 38.1, 6.7, 0.7)	3.778^c	71.96^d	34.09^{bc}	0.47
NPSB (64, 46, 6.7, 0.7)	4.689^b	95.9^{ab}	34.98^a	0.47
NPSB (69, 60, 6.7, 0.7)	5.289^a	103.60^a	35.71^a	0.49
NPSB (64,46, 0, 0)	4.356^b	91.22^{bc}	33.65^c	0.47
LSD (0.05)	0.5053	8.41	0.98	1.8
P-Value	< 0. 001	< 0. 001	< 0. 001	<0. 471
CV (%)	9.0	5.7	0.7	3.8

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation; FT_PP= of fertile tillers per plant; FG_PP = fertile grain per panicle; TSW=thousand seed weight; HI= Harvest index, Means in column followed by the same letters are not significantly different at 5% level of Significance.

Grain yield

The analysis of variance for the grain yield revealed significant ($p<0.001$), ($p<0.05$) and ($p<0.001$) difference for blended fertilizer rates, sowing methods and their interaction effect, respectively (Table 6). Increased trends of NP in the blended rate under different sowing methods for each and every interaction treatment produced significantly higher grain yield over the lowest rate and the control treatment. The highest mean grain yield (5708 kg ha^{-1}) was recorded from the blended fertilizer rate that contain high level of NP, which was NPSB (69, 60, 6.7, 0.71) kg ha^{-1} under dibbling sowing method and this was followed by the same sowing method with NPSB (64, 46, 6.7, 0.71) kg ha^{-1} blended fertilizer rate with a mean grain yield of 5196 kg ha^{-1}. Whereas, the lower (2504) and (2528 kg ha^{-1}) gain yields were recorded from the interaction effect of control treatment and the lowest blended fertilizer rate NPSB (18.1, 38.1, 6.7, 0.71) kg ha^{-1} combined with broadcast and dibbling sowing methods, respectively. Significance difference was also observed between the previously used blanket recommendations NP (64, 46) kg ha^{-1} without changing the level of NP in both treatments. The significance variation in mean grain yield might be due to the availability of S and B in the blended rate, S involves in plant protein synthesis and improve N uptake by the plant and B is associated with cell division, flowering and fruiting and then finally increases grain yield of rice. The results clearly showed that the yield of rice could be maximized by the combined effect of increased blended fertilizer rate under dibbling sowing methods. This could be attributed to the availability essential macro and micro nutrients that enhance the productivity of rice. This result confirms the finding of Anbessa *et al.* (2016) who indicated that the yield of rice was significantly (P < 0.001) increased by high level of N applied up to a rate 138 kg P ha^{-1} and the grain yield can be achieved by 47 %. The author also reported that by applying 92 kg P ha^{-1} and 46 kg P ha^{-1} 36.2 and 32.5 % grain yield of rice can be achieved, respectively compared to the control that received no NP at all. Similar result was reported by Bereket *et al*. (2014) who reported that P application of 46 kg P ha^{-1} increased significantly grain and straw yields by 38 % and 46 %, respectively than control in wheat.

Likewise the yield increment in the combined effect of dibbling sowing method with increased rates of blended fertilizer might be due to readymade availability of NP from the blended rate and better nutrient use efficiency. Not only in the dibbling but also in the drilling sowing methods, there might be low nutrient loss for highly soluble source of nutrients like urea through volatilization, immobilization, run off and nitrification due to placement of fertilizer in row side by side with the rice seed can be easily uptake by the roots system. This finding is similar to that of Rehm and Lamb (2009) who found that placement of fertilizer near the maize seed at the time of sowing increased early growth, P uptake and yield which can be an effective management practice with minimal risk nutrient loss. Similar finding wos reported by Bautista et al (2000) who concluded that placement of any N source fertilizers with simultaneous soil cover was effective in minimizing N losses through different mechanisims and increased N use efficiency in rice production. From the above results, it may be concluded that use of amended blended fertilizer rates for N and P under dibbling sowing method was better for both improving crop growth and increased crop productivity in rice production systems.

Table 6. Grain yield as influenced by the interaction effect of blended fertilizer rate and sowing methods.

Sowing methods	Fertilizer rate kg ha^{-1}				
	Control (0, 0, 0, 0)	NPSB (18.1, 38.1, 6.7,0.7)	NPSB (64, 46, 6.7, 0.7)	NPSB (69, 60, 6.7, 0.7)	NPSB (64,46, 0, 0)
(Broadcast)	2504^{h}	2653^{gh}	3936^{f}	4503de	4000^{f}
(Dibbling)	2528^{h}	3668^{f}	5196^{b}	5708^{a}	4524^{d}
(Drilling)	2682^{h}	3053^{g}	4675^{cd}	5032^{bc}	4086^{ef}
LSD (0.05)	421.61				
P- Value	< 0. 001				
CV (%)	5.5				

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation; Means in column followed by the same letters are not significantly different at 5% level of Significance.

Straw yield

Straw yield is obtained by subtracting the grain yield from the above ground biomass. Straw yield of rice varied significantly (P <0 .01) among the treatments of sowing method and blended fertilizer rates. The increasing level of NP in the blended fertilizer rates combined with the dibbling sowing method positively increased the straw yield of rice. The maximum mean straw yield (5812 kg ha^{-1}) followed by (5788 kg ha^{-1}) was recorded from the treatments fertilized with NPSB (64, 46, 6.7, 0.71) and (69, 60, 6.7, 0.7) kg ha^{-1} under the dibbling sowing method (Table 7). Whereas the minimum 2767 and 2646 kg ha^{-1} mean straw yield was recorded from the control treatment combined with broadcast and dibbling sowing methods, respectively. Generally, each and every treatment interaction effect produced higher straw yield than the control. These results indicated that under the given experimental conditions, combined application of blended fertilizer rate amended with urea and TSP and under dibbling and drilling sowing method significantly improved straw yield of rice.

The increase in straw yield might be attributed to application of increased amended rates of NP in blended fertilizer that enhanced vigorous vegetative growth and increased dry matter accumulation as a result of increased vegetative growth favored by enhanced nutrient uptake by rice plants. This result is like the findings of Dereje et al (2017) who reported an increasing levels of applied N up to 138 kg ha^{-1} increased straw yield of rice significantly ($P \leq 0.01$) from

4544.8 kg ha^{-1} in the control treatment to 7002.1 kg ha^{-1} with application of 138 kg P ha^{-1} and similar to that increasing the levels of applied P also increased straw yield of rice significantly (P ≤ 0.05) up to 60 kg P ha^{-1}.

Table 7. Straw yields as influenced by the interaction effect of blended fertilizer rate and sowing methods.

Sowing methods	Blended fertilizer rate kg ha^{-1}				
	Control (0, 0, 0, 0)	NPSB (18.1, 38.1, 6.7,0.7)	NPSB (64, 46, 6.7, 0.7)	NPSB (69, 60, 6.7, 0.7)	NPSB (64,46, 0, 0)
(Broadcast)	2767	3441^{g}	4259^{def}	4856^{bc}	4488^{cde}
(Dibbling)	2646	4106^{ef}	5812^{a}	5788^{a}	4780^{bcd}
(Drilling)	2805	3838^{fg}	5014^{bc}	5072^{b}	4486^{cde}
LSD (0.05)	559.751				
P- Value	< 0. 016				
CV (%)	7.6				

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation; Means in column followed by the same letters are not significantly different at 5% level of Significance

Partial budget analysis

The partial budget analysis showed that net benefit increase with increasing variable costs across all treatments except treatments 2, 3 and 4 under broadcast sowing method and 10 and 11, 15 under dibbling and drilling, respectively. All these treatments are dominated and finally not considered for further analysis of MRR.

Table 8. Dominance analysis for the treatment combination of different blended rates and sowing methods

Trt	Treatment Combinations sowing method + NPSB rate (kg ha^{-1})	TVC (birr)	Net Benefit (birr)	DA	Rank
Trt1	(0, 0, 0, 0) + Broadcast	833.3	21312.5	ND	1
Trt12	(0, 0, 0, 0) + Drilling	1388.9	22156.4	ND	2
Trt10	(0, 0, 0, 0) + Dibbling	1527.8	20671.8	D	
Trt2	(18.1, 38.1, 6.7,0.7) + Broadcast	2472.2	21536.1	D	
Trt13	(18.1, 38.1, 6.7,0.7) + Drilling	3027.8	24473.3	ND	3
Trt6	(18.1, 36.1, 6.7,0.7) + Dibbling	3305.6	29191.1	ND	4
Trt5	(64,46, 0, 0)+ Broadcast	3754.2	31696.4	ND	5
Trt3	(64, 46, 6.7, 0.7)+ Broadcast	4154.1	30558.1	D	
Trt15	(64,46, 0, 0)+ Drilling	4448.7	31651.9	D	
Trt8	(64,46, 0, 0)+ Dibbling	4726.4	35043.1	ND	6
Trt4	(69, 60, 6.7, 0.7)+ Broadcast	4752	34941.7	D	
Trt14	(64, 46, 6.7, 0.7)+ Drilling	4848.6	36328.2	ND	7
Trt9	(64, 46, 6.7, 0.7)+ Dibbling	5126.3	40902.9	ND	8
Trt11	(69, 60, 6.7, 0.7)+ Drilling	5307.6	38662.1	D	
Trt7	(69, 60, 6.7, 0.7)+ Dibbling	5585.3	44331.1	ND	9

DA= Dominance analysis, D = Dominated treatments, ND = non dominated treatments, TVS = Total variable cost, MRR = Marginal rate of return.

Finally, MRR was calculated for the treatments that showed no dominance to compare the increments in cost and benefits between pairs of the treatments. The higher (1698.3 and 1647.4) % MRR were obtained from treatments fertilized with NPSB (18.1, 38.1, 6.7, 0.71) kg ha^{-1} followed by NPSB (64, 60, 6.7, 0.7) kg ha^{-1} both under dibbling sowing method, respectively and thus treatments could be considered to have an economic advantage over the use of other alternative combinations. Considering the assumption of minimum acceptable MRR by farmers as 100% to adopt a new technology in this study, all except treatments 2, 3 and 4 under broadcast sowing method and 10 and 11, 15 under dibbling and drilling method, respectively were non dominated and then acceptable. However, the most profitable treatments were blended fertilizer at the rates of NPSB (18.1, 38.1, 6.7, and 0.71) and NPSB (64, 60, 6.7, 0.7) kg ha^{-1} both under the dibbling sowing method. Therefore, though the net return of blended rate under dibbling sowing method seemed inferior to the broadcast and drilling planting methods. Considering the best planting method, fertilizer type to be applied and rate on rice cultivation is economically profitable since rice producers can gain income to cover the total costs of production from the straw and grain yield.

Table 9. Marginal rate of return analysis for non dominated treatments

Selected treatments	Treatment Combination	TVC (birr/ha)	Marginal costs (birr/ha)	Net benefit (birr/ha)	Marginal net benefit (birr/ha)	MRR in (%)
Trt1	(0, 0, 0, 0) + Broadcast	833.3		21312.5	-	-
Trt12	(0, 0, 0, 0) + Drilling	1388.9	555.6	22156.4	843.9	151.9
Trt13	(18.1, 36.1, 6.7,0.7) + Drilling	3027.8	1638.9	24473.3	2316.9	141.4
Trt6	(18.1, 36.1, 6.7,0.7) + Dibbling	3305.6	277.8	29191.1	4717.8	1698.3
Trt5	(64,46, 0, 0)+ Broadcast	3754.2	448.6	31696.4	2505.3	558.5
Trt8	(64,46, 0, 0)+ Dibbling	4726.4	972.2	35043.1	3346.7	344.2
Trt14	(64, 46, 6.7, 0.7)+ Drilling	4848.6	122.2	36328.2	1285.1	1051.6
Trt9	(64, 46, 6.7, 0.7)+ Dibbling	5126.3	277.7	40902.9	4574.7	1647.4
Trt7	(69, 60, 6.7, 0.7)+ Dibbling	5585.3	459	44331.1	3428.2	746.9

Conculuation and Recommendation

Agronomic practices like nutrient management and method of sowing are the important yield limiting factors for rice production and productivity. Therefore, rice is a highly nutrient feeder crop and positively affected by both N and P levels. Dibbling and drilling sowing methods integrated with amended blended fertilizer rate appreciably affect all the studied crop phenology, growth parameters, yield and yield components of rice and resulted in a significant variation, with low to high magnitude of variability. The significant effects observed were increased application of amended blended fertilizer rates positively affected grain yield and yield components when rice was planted under dibbling and drilling sowing methods than the control and the lower blended rate under broadcast sowing method. The current research showed the interaction effect of sowing methods and blended fertilizer rates significantly affected the grain yield, biomass yield and straw yield. The maximum 5,708 and 11,496 kg ha^{-1} grain and biomass yield were recorded from plots treated with amended blended rates NPSB (69, 60. 6.7, 0.71) kg ha^{-1} under dibbling sowing method.

Although claiming economic benefits based on data obtained from small plots of one year experiment is doubtful, from this preliminary study in one growing season at one location application of NPSB (64, 46, 6.7, 0.71) kg ha^{-1} blended fertilizer rate under the dibbling sowing method is most profitable to producers considering all the agronomic performance.

Therefore, based on the results of the study and the above summary, it can be recommended that;

1. Supplemented NP level from other source on the site specific blended fertilizer used in the area up to the rate of NPSB (69, 60, 6.7.0.71) kg ha^{-1} under dibbling sowing method improve growth parameters and yield traits, optimum grain yield and straw yield rice under rain fed condition in Tselemti Woreda and in areas where the rainfall distribution and soil type is similar with the study Woreda.
2. In terms of both economic and biological yield dibbling sowing method at the rate of NPSB (64, 46, 6.7.0.71) kg ha^{-1} amended rate gives highest benefit to producers in the area.
3. Since the finding was based on one season and one location experiment further research over years and in multiple locations should be needed

Acknowledgments

The authors thank Dr. Yemane Tsehaye for his visit to the research site and for his critical comments during the visit. The authors are gratefull to Tigray Agricultural Research Institute (TARI) and Maitsebri - Shire Agricultural Research Center for financing the graduate study.

Reference

Abebe Getu (2012): Soil characterization and evaluation of slow release urea fertilizer rates on yield components and grain yields of wheat and tef on Vertisols of jamma Woreda of

south wollo zone, amhara region. Unpublished MSc Thesis, Haramaya University, Haramaya, Ethiopia.
Africa Rice Center: (2011). Boosting Africas Rice Sector: A research for development strategy 2011±2020. *Cotonou, Benin*.
Alem,R and Fetien A (2015): Yield Performance of Rice (Oryza sativa L.) using FYM and Inorganic Fertilizers in Tselemti Woreda of north-western Tigray, Ethiopia. *J Biol Agri Healthcare*. 9: 30-41.
Anbessa B, Fayisa G and Dereje W. (2016): Influence of phosphorous and nitrogen fertilizer rate on grain yield of rice at Kamashi Zone of Benshal-gul Gumuz Region, Ethiopia. Journal of World Economic Research. Vol. 5, No. 2, pp. 8-14.
Awan TH, Ali ME, Safdar MM, Ashraf and Yaqub. (2007): Economic effect of different plant establishment techniques on rice production. *J. Agric. Res*. 45(1): 73-81.
Bahmanyar MA and Mashaee SS (2010): Influences of nitrogen and potassium top dressing on yield and yield components as well as their accumulation in rice (*Oryza sativa*). *African Journal of Biotechnology*, 9 (18), pp. 2648-2653.
Bashour I and Sayegh AH (2007): Methods of analysis for soils of arid and semi-arid regions. FAO.
Bautista EU Suministrado DC and Koike M (2000): Mechanical deep placement of fertilizer in puddle soils. *Journal of the Japanese Society of Agricultural Machinery*, 62 (1), pp.146-157.
Berhe T Gebretsadik Z Edwards S and Araya H (2011): Boosting tef productivity using improved agronomic practices and appropriate fertilizer. In Achievements and Prospects of Tef Improvement. *Proceedings of the Second International Workshop*; pp. 133-140.
Black CA Evans DD White JL Ensminger LE and Clark FE (1965): Method of soil analysis, Part 2. ASA, Inc. Madison, Wis, USA.Bouyoucos J (1962): Hydrometer method improved for making particle size analysis of soil.
Bremner JM and Mulvaney CS (1982): Nitrogen - Total, Methods of soil analysis. Part 2-Chemical and microbiological properties. American Society of Agronomy Madison, Wis. 9 (2):595-624.
CSA (Central Statistical Agency) (2007-2016): Statistical report on area and production of crops. Addis Ababa, Ethiopia.
Defoer T Budelman A Toulmin C and Carter SE (2000): Building common knowledge: Participatory learning and action research. Royal Tropical Institute, Amsterdam, The Netherlands, 207.
Dereje G Walelign B Giddisa A Solomon H and Hagos A (2017): Participatory evaluation and determination of N and P fertilizer application rate on yield and yield components of upland rice (NERICA-4) at Bambasi Woreda, Benishangul-Gumuz Regional State. *Adv Crop Sci Tech* 5: 303.
EIAR (Ethiopian Institute of Agricultural Research) (2011): Challenges and opportunities of rice in Ethiopian Agricultural Development, Edt. Kebebew A., Dawit A., K. SHIRATORI, Abebe K., FRG II Project, Empowering Farmers' Innovation, Series No. 2, *EIAR-JICA.*
EthioSIS (Ethiopian Soil Information System) (2013): Soil analysis report. Agricultural Transformation Agency (Unpublished).
Fageria NK, Moreira A and Coelho AM (2011): Yield and yield components of upland rice as influenced by nitrogen sources. *Journal of Plant nutrition*, 34 (3), pp.361-370.

Fairhurst T, Witt C, Buresh R, Dobermann A and Fairhurst T (2007): A practical guide Book to nutrient management for rice. *Int. Rice Res. Inst*.

FAO (Food and Agriculture Organization) (2012): FAO STAT. http://faostat.fao. org/default. aspx.

Halima R, Jerome P and Balthazar M (2017): Response of rice to nitrogen and phosphorus applied on typical soils of Dakawa Irrigation Scheme, Morogoro, Tanzania. *Imperial Journal of Interdisciplinary Research*. 3(6): Pp. 379-380.

Hegde and Hegde V (2013): Assessment of global rice production and export opportunity for economic development in Ethiopia. *Int. J. Sci. Res*, 2, pp. 257-260.

Horneck DA, Sullivan DM, Owen JS and Hart JM (2011): Soil test interpretation guide. [Corvallis, Or.]: Oregon State University, Extension Service.

Jackson ML (1967): Soil chemical analysis. Practice Hall of India. New Delhi.

Jones JB (2003): Agronomic Handbook: Management of crops, soils, and their Fertility. CRC Press LLC, Boca Raton, FL, USA. P. 482.

Liu L, Waters DL, Rose TJ, Bao J and King GJ (2013): Phospholipids in rice: significance in grain quality and health benefits: a review. *Food chemistry*, 139 (1-4), pp. 1133-1145.

Mattson N, Leatherwood R and Peters C (2009): Nitrogen: All forms are not equal. Cari Peters JR Peters Inc, p. 61.

MoARD (Ministry of Agriculture and Rural Development) (2010): National Rice Research and Development Strategy of Ethiopia. Addis Ababa, Ethiopia.

Nachimuthu VV Muthurajan R Duraialaguraja S Sivakami R Pandian BA Ponniah G Gunasekaran K Swaminathan M Suji KK and Sabariappan R (2015):Analysis of population.

NRRDSE (National Rice Research and Development Strategy of Ethiopia) (2010): Ministry of Agriculture and Rural Development, Addis Ababa, Ethiopia.

Oyewole CI Ajayi O and Ojuekaiye RO (2010): Evaluation of yields of seven upland rice (*Oryza sativa*.L) cultivars sown by three methods in Anyigba, Kogi State, Nigeria. *African Journal of Agricultural Research*, 5(16), pp. 2089-2096.

Rehm GW and Lamb JA (2009): Corn response to fluid fertilizers placed near the seed at planting. *Soil Science Society of America Journal*, 73 (4), pp.1427-1434.

Rhoades JD (1982): In methods of soil analysis, Part 2. Second Edition (A.L. Page. Miller and D.R. Keeney, Eds.). American Society of Agronomy. Madison, USA.

Savant NK and Stangel PJ (1990): Deep placement of urea supergranules in transplanted rice: principles and practices. Fertilizer research, 25(1), pp.1-83.

Taddesse E (2009): Rice (Oryza sativa L.) cultivars: Morphology and Classification part II. Experimental Station Bulletin 66. Addis Ababa University, College of Agriculture, Dire Dawa (Ethiopia). 73p.

Walkley A and Black IA (1934): An examination of the method for determining soil organic matter and proposed chromic acid titration method. *Soil Science*, (37):29-38.

Zelalem A, Tekalign T and Nigussie D (2009): Response of potato (Solanum tuberosum L.) to different rates of nitrogen and phosphorus fertilization on vertisols at Debre Berhan, in the central highlands of Ethiopia. *African Journal of Plant Science*, 3 (2), pp.016-024.

Zenna S, Gebre-Tsadik Z., BerheT (2008): Moving up in Ethiopia. Rice Today.

Response of Onion (*Allium cepa* L.) to Blended Fertilizer (NPSZnFe) on Yield and Yield Components under Irrigation Condition in Raya Azebo, Northern Ethiopia

Gebremeskel Gebrekorkos* and Hayelom Berhe

Ethiopian Institute of Agricultural Research, Mehoni Agricultural Research Center

*Correspondence email: gebremeskel12@gmail.com

Abstract

An experiment was conducted on Mehoni Agricultural Research Center testing site at Fachagama site in 2018 cropping season to determine optimum blended fertilizer rate and to assess economic feasibility of blended fertilizers for onion yield. The treatments were laid out in randomized complete block design (RCBD) in factorial arrangement with three replications. The treatments were: four rates of blend fertilizer (NPSZnFe) i.e.150, 200, 250 and 300 kg ha^{-1}; three rates of nitrogen (N) (69, 92 and 115 kg ha^{-1}); blanket recommended rate and absolute control. Analysis of the data showed no significance difference on bulb height, bulb diameter, bulb weight and unmarketable bulb yield. There were significance differences on marketable bulb yield and total bulb yield.The highest bulb height, bulb diameter and bulb weight were recorded from the combination of 200 kg ha^{-1} NPSZnFe and 69 kg ha^{-1} N. The highest marketable bulb yield (32.44 t ha $^{-1}$) and highest total bulb yield (34.79 t ha $^{-1}$) were recorded at the combination of 200 kg /ha NPSZnFe blended fertilizer and 69 kg ha^{-1}N. Partial budget analysis revealed that the maximum net benefit, (154490 ETB ha^{-1}) was obtained from the combination of 200 kgha^{-1} blended fertilizer and 69 kg ha^{-1} N.

Keywords: Blended fertilizer, onion, yield, economic feasibility.

Introduction

Onion (*Allium cepa* L.) is the most important bulb crop cultivated commercially in most parts of the world. Onion belongs to the genus Allium of the family *Alliaceae* (Hanelt 1990; Griffiths et al 2002). The crop is grown for consumption both in the green state as well as in mature bulbs. Onions exhibit particular diversity in the eastern Mediterranean countries, through Turkmenistan, Tajikistan to Pakistan and India, which are the most important sources of genetic diversity and believed to be center of origin (Brewster 2008). Onion is one of the most popular and the most cultivated vegetables in Ethiopia in general and in Tigray region in particular (Hailu et al 2015).

Low soil fertility is one of the most important constraints limiting onion production. Nitrogen (N) and phosphorus (P) are often referred to as the primary macronutrients because of the probability of plants being deficient in these nutrients and because of the large quantities taken up from the soil relative to other essential nutrients (Marschner 1995). Since the starting of application in the early 1970's, fertilizer use in Ethiopia had focused mainly on the use of N and P fertilizers in the form of blanket recommendation where urea and di-ammonium phosphate (DAP) were being applied for almost all crops. Such unbalanced application of plant nutrients may aggravate the depletion of other important nutrient elements in soils (Fayera et al 2014). In the study area (southern zone of Tigray), field experimentations have not been conducted on fertilizer rates and fertilizer types, particularly for blended fertilizers on onion. The soils of Raya Azabo Wereda lack the essential elements such as sulfur (S), iron (Fe) and zinc (Zn) in addition to N and P (ATA and MoA 2014). Balanced fertilizers that contain macro and micronutrients are crucial to increase the production of crops in the study area. Hence, in Southern Zone of Tigray, particularly in the Raya Azebo Wereda, ten most common blended fertilizers were recommended. From these ten blended fertilizers, NPSFeZn is the most dominant blended fertilizer recommended for the area. Optimize the production of onion by applying the appropriate blended fertilizer rate is important in the study area, Raya Azebo. This study was initiated to determine optimum blended fertilizer rate onion production at Raya Azebo WoredaWoredas and to assess economic feasibility of blended fertilizer rate for onion production.

Material and Methods

Study site description

The experiment was carried out in Southern Zone of of Tigray Regional State, especially at Mehoni Agricultural Research Center (MhARC) testing station under irrigation conditions in 2018 cropping season. It is located at 668 km from the capital Addis Ababa and about 120 km from Mekelle, the capital city of Tigray Regional State. Geographically, the experimental site is located at 12.70° N latitude and 39.70° E longitude with an altitude of 1578 m.a.s.l. The site receives a mean annual rainfall of 539 mm with an average minimum and maximum temperature of 12.81 and 23.24°C, respectively (MhARC 2016). The major cultivated cereal crop in the study area includes tef, sorghum and maize. The major cultivated vegetable crops are also onion, tomato and pepper.

Experimental design and treatments

The treatments were laid out in RCBD in factorial arrangement with three replications. Four rates of blend fertilizer (150, 200, 250 and 300 kg ha^{-1}), three rates of N (69,92 and 115 kg ha^{-1}), blanket recommended rate and absolute control were included as treatments as displayed in Table 1.

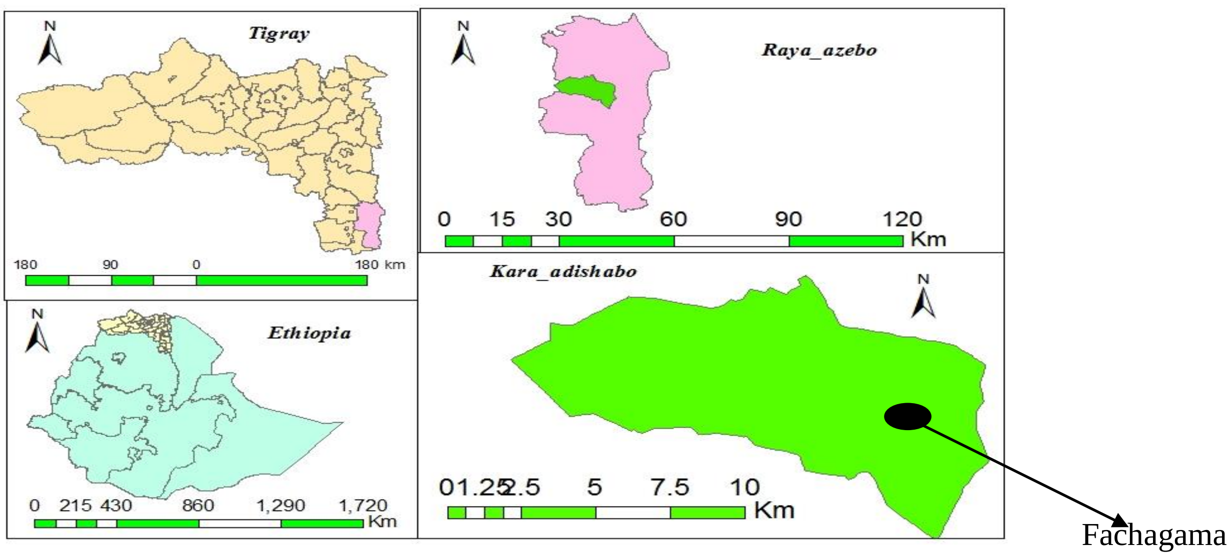

Figure 1. Map of the study area at Raya Azebo, Tigray, Ethiopia

The gross size of the experimental plot was 3m by3.2m (9.6m^2) with spacing of 40, 20 and 10 cm between furrow, row and plants, respectively. Bombay red variety was used as test crop for all experimental units.

Table 1. Treatment Combinations

Treatments	NPSZnFe	Urea
1	0	0
2	150	150
3	200	150
4	250	150
5	300	150
6	150	200
7	200	200
8	250	200
9	300	200
10	150	250
11	200	250
12	250	250
13	300	250
14	Recommended NP (DAP and urea)	

Field management

Land preparation was done at the beginning with tractor and leveled before planting. Urea and DAP were used as the sources of N and P, respectively. Di-ammonium phosphate and bended fertilizer were applied at transplanting time whereas urea was applied in two splits i.e. 20 days after transplanting and 30 days after the first urea applied. Onion was transplanted when 3-4 true leaves emerged that was after 55 days from the time of sowing. The transplanting time was in the morning in order to decrease the shocking of the plant. Ridomil and karate wereapplied to protect the fungal disease and insect at recommended rate, respectively and other cultural management practices were done according to the national recommendation for all experimental units.

Data collection

Soil data

Soil samples were taken before planting from the experimental site were sent to Werer and Debrezeit Agricultural Research Centers for analysis of some physical and chemical properties of the soil.

Morphological traits, Bulb yield and yield components

Ten plants from the net plot area were pre tagged to collect data of plant height. It was measured using meter from the soil surface up to the tip of the leaves at bulb development stage. Ten plants from the net plot area were pre tagged to collect data of average bulb weight and expressed in gram. Ten plants from the net plot area were pre tagged to collect data of average bulb diameter and expressed in centimeter. Ten plants from the net plot area were pre tagged to collect data of average bulb diameter and expressed in centimeter.

Marketable bulb yield was estimated by weighing total clean, healthy and undamaged bulbs per net plot and converted to t ha^{-1}, while unmarketable bulb yield by weighing total decay, physiological disorder such as thick necked, split and bolters per net plot and converted to t ha^{-1}. Total bulb yield was obtained from summation of marketable and unmarketable bulbs. The data were collected from middle rows of a net plot area where the two outer most rows of each treatment were left as border effects.

Statistical analysis

All data were subjected to the analysis of variance (ANOVA) using the Statistical Analysis System (SAS) (9.1) software computer package (SAS Institute 2004) and significance difference among the treatment means was computed with Duncan's Multiple Range Test (DMRT) at 5% probability level (Gomez and Gomez 1984).

Economic analysis

Economic analysis was performed to investigate the economic feasibility of the treatments by using partial and marginal analyses. The gross income was obtained by multiplying average marketable bulb yield by the average open market price (Birr kg^{-1}). Total variable cost was the cost of fertilizers, cost of fertilizer application and seed cost. Labor costs to apply fertilizer were calculated considering 75 ETB per person per day: Net benefit = Gross income - total variable cost [International Maize and Wheat Improvement Centre (CIMMYT) 1988].

Dominance analysis was conducted by listing the treatments according to increasing order of costs that vary and comparing the net benefit of the treatments. Treatments found with decreasing net benefit while, total cost that vary increases were eliminated (Dominated). Marginal rate of return was computed for those which were non dominated. Marginal rate of return (MRR) was calculated as the change in net benefit (NB) divided by the change in total variable cost (TVC) of the successive net benefit and total variable cost levels (CIMMYT 1988).

$$\text{Marginal rate of return (MRR)} = \frac{\text{Marginal increase in net benefit}}{\text{Marginal increase in cost}}$$

Result and Discussion

Soil before planting

Analysis of soil samples for texture, soil reaction (pH) and electrical conductivity of soil extract (ECe) for samples collected before planting is presented in Table 2. The soil of the experimental site has a proportion of 30% sand, 44% silt and 26% clay and according to the soil textural triangle, it is texturally classified as loam (Table 2). As described in Table 2, the EC of the experimental site was 0.75 dS/m. According to Hazelton and Murphy (2007) soils having the EC less than 4 are considered as non saline and suitable for agriculture production. According to Tekalign (1991), a soil of the experimental site is strongly alkaline.

Table 2 .Soil texture, pH and EC of the experimental field before planting.

Soil parameters	Unit	Value
Sand	%	30
Silt	%	44
Clay	%	26
Textural class		Loam
pH	-	8.04
ECe		0.75

Morphological, bulb yield and yield components

As indicated in Table 3, the analysis of variance showed no significance difference on bulb height, bulb diameter, bulb weight, plant height and unmarket bulb yield. The highest bulb height, bulb diameter and bulb weight were recorded from the combination of 200 kgha^{-1} blended fertilizer and 69 N kgha-1 (Table 4).

Table 3. Analysis of variance (ANOVA) for Days to maturity, Plant height, Bulb weight, Bulb height, Bulb diameter, Marketable bulb yield, unmarketable yield and Total Bulb yield of onion

SOV	BH	BD	BW	PH	MY	Un	Tot
Treatment	0.12	0.09	17.58	9.22	29.77**	0.18	28.63**
Replication	0.19	0.02	149.21	56.73	72.17	0.44	81.47
Eror	0.07	0.065	33.93	15.50	5.52	0.23	4.74
CV	6.15	5.43	10.32	9.65	8.12	21.38	6.98

SOV= source of variation,BH= bulb height , BD= bulb diameter , BW= bulb weight , PH= plant height ,MY = Marketable bulb yield , Un = unmarketable yield , Tot = total bulb yield.

Marketable bulb yield

Application of NPSZnFe blended fertilizer rate and N affected the marketable yield of onion. Marketable bulb yield showed significant ($p<0.01$) variation due to the effect of the fertilizers (Table 3). As indicated in Table 4, the maximum marketable bulb yield (32.44 t ha^{-1}) was obtained from the combined application of 200 kg ha^{-1} NPSZnFe and 69 N kg ha^{-1}. While, the lowest marketable bulb yield (19.86 t ha^{-1}) was obtained from unfertilized plots. The lowest yield obtained in unfertilized plots which might be due to poor fertility of the soil. This increment in marketable bulb yield with the fertilizer which contained both macro and micro plant nutrients as compared to the control is an indicator of low soil fertility level. This is in line with Nimona et al (2018) who reported that blended fertilizer NPSZnB and urea brought highly significant difference on the marketable pod yield of pepper. Similarly, Solomon et al (2019) reported that application of blended fertilizers significantly affects tuber yield of potato.

Table 4. Effect of fertilizers on days to maturity, plant height, bulb weight, bulb height, bulb diameter, marketable bulb yield, unmarketable yield and total bulb yield of onion

TRT	NPSZnFe (kg ha^{-1})	Urea (kg ha^{-1})	PH (cm)	BW (g)	BH (cm)	BD (cm)	MBY (t ha^{-1})	Un MBY (t ha^{-1})	TBY (t ha^{-1})
1	0	0	37.53	49.40	4.08	4.24	19.86 d	2.47	22.33 f
2	150	150	43.63	57.67	4.56	4.77	30.39ab	2.73	33.12ab
3	200	150	43.53	59.63	4.95	5.02	32.44 a	2.35	34.79 a
4	250	150	40.47	55.00	4.25	4.63	30.68 ab	2.08	32.76 ab
5	300	150	40.67	57.07	4.37	4.80	31.61ab	2.35	33.95 a
6	150	200	39.07	57.00	4.52	4.84	29.25abc	2.14	31.39abcde
7	200	200	39.93	55.53	4.49	4.81	29.33abc	2.04	31.37abcde
8	250	200	40.90	55.73	4.50	4.63	29.92ab	1.97	31.89abcd
9	300	200	40.13	59.40	4.32	4.71	28.34abc	2.65	30.99abcde
10	150	250	39.87	56.67	4.42	4.55	29.72 abc	2.19	31.92abc
11	200	250	42.53	56.63	4.40	4.64	30.85ab	1.89	32.74ab
12	250	250	39.00	56.47	4.32	4.81	27.36 bc	2.27	29.63bcde
13	300	250	42.2	58.07	4.23	4.67	30.12ab	2.12	32.24 ab
14	Rec. NP (100kg DAP and 100 kg urea)		41.40	56.37	4.50	4.73	25.43c	2.35	27.78 de
Cv			9.65	10.32	6.15	5.43	8.1	21.4	7.0

BH= bulb height, BD= bulb diameter, BW= bulb weight, PH= plant height, MY = Marketable bulb yield, Un=unmarketable yield Tot = total bulb yield

Total bulb yield

Similar to the marketable bulb yield, analysis of the data showed significant ($P<0.01$) difference on the total bulb yield due to the effect of fertilizers (Table 3). The maximum total bulb yield (34.79 t ha^{-1}) was recorded from the application of 200 kgha^{-1} NPSZnFe and 69 kgha^{-1} ~~of~~ N (Table 4).

Economic analysis

As indicated in Table 5, except for the combined treatments (0 with 0, 100 kg DAP with 100 kg urea , 150 NPSZnFe with 150 urea , 200 NPSZnFe with 150 urea), all other treatments were dominated. This means the net benefits that were obtained from these treatments were lower than the net benefit obtained from the treatments with lower variable cost and there were no proportional increments in the net benefits with increment in variable cost. The partial budget analysis indicated that application of the blended fertilizer combined with urea gave higher gross profit, net return and marginal rate of return compared to the control.

Table 5. Partial budget and dominance analysis of fertilizers

NPSZnFe (kg ha^{-1})	Urea (kg ha^{-1})	Total cost	Gross benefit	NET benefit	Dominat ion rank	Marginal cost	Mariginal benefit	MRR
0	0	2500	99300	96800	-	-	-	-
100 DAP	100	5490	127150	121660	ND	2990	24860	831.44
150	150	6985	151950	144965	ND	1495	23305	1558.86
200	150	7710	162200	154490	ND	725	9525	1313.79
150	200	7840	146250	138410	D			
150	250	8335	148600	140265	D			
200	200	8430	146650	138220	D			
200	250	8430	154250	145820	D			
250	150	8425	153400	144975	D			
250	200	9200	149600	140400	D			
300	150	9330	158050	148720	D			
250	250	9875	136800	126925	D			
300	200	9920	141700	131780	D			
300	250	10645	150600	139955	D			

Where; D= dominated treatment; ND = Non dominated treatment

Data presented in Table 5 indicated the economic analysis of bulb yield affected by fertilizer rates. It is clear from the data that the maximum (154490 ETB ha^{-1}) net benefit was obtained from the combination of 200 kg ha^{-1} NPSZnFe and 150 kg ha^{-1} urea, while the minimum (96800 ETB ha^{-1}) net benefit was noted from the unfertilized treatment. The result showed general decrease in benefit cost ratio with increasing levels of the fertilizers. According to CIMMYT

(1988), application of fertilizer with the marginal rate of return above the minimum level (100%) is economical. Similarly, Solomon et al. (2019) reported maximum net benefit and marginal rate of return (4453.6%) from the application of blended fertilizer NPS on potato. In line with this result, Nimona et al (2018) reported that application of 150kgha^{-1} NPSZnB +44 kg N ha^{-1} generated the highest net benefit (168,070 ETB ha^{-1}) with 5365% marginal rate of return (MRR) on pepper yield .

Conclusion and Recommendation

Production and productivity of onion in the study area and in similar soil and climatic conditions in Raya valley can be increased by using the combined application of blended fertilizers and urea. The combined application of different rates of the blended fertilizer and urea did not significantly affect bulb height, bulb diameter, bulb weight, plant height and unmarkatable bulb yield. Maximum bulb height, bulb diameter and bulb weight were obtained from the combined application of 200 kg/ha blended fertilizer and 150 kg/ha urea. With regard to the marketable bulb yield and total bulb yield, there were highly significant difference due to the application of different rates of blended fertilizer and urea. Maximum marketable bulb yield (32.44 t ha^{-1}) and maximum total bulb yield (34.79 t ha^{-1}) were obtained from the combined application of 200 kg ha^{-1} NPSZnFe blended fertilizer and 69 N kg ha^{-1}. The minimum marketable (19.86 t ha^{-}1) and total (22.33 t ha^{-1}) yields were obtained from the unfertilized treatment. The maximum net benefit (154490 ETB ha^{-1}) was obtained from the combined of 200 kg/ha blended fertilizer and 150 kg /ha urea, while the minimum (96800 ETB ha^{-1}) net benefit was noted from the unfertilized treatment. Based on the result of the study and the above summary, it can be recommended that:

- Application of 200 kg/ha blended fertilizer (NPSZnFe) combined with 150 kg /ha urea was tentatively recommended for onion production in the study area
- Soil test based application of fertilizer should be done on site specific conditions because the recently introduced fertilizer has made change in yield and the availability of the element may vary depending on the nature of the soil.
- Further research experiments on different blended fertilizer types and on rate to validate these results in multiple locations and seasons should be carried out to identify best blended fertilizer rate for sustainable onion production.

Acknowledgement

The authors would like to thank God for his grace, love and strength that I got to do this work. The authors gratefully acknowledge Ethiopian Institute of Agricultural Research (EIAR) and Mekoni Agricultural Research Center for their financial support of this study.

Reference

Black CA (1992): Soil fertility evaluation and control. Lewis Publishers, USA

Brewster JL (2008).Onions and other vegetable alliums.2nd ed. CAB International. North America.

CIMMYT (International Maize and Wheat Improvement Centre) (1988): From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition,Mexico. D.F conference held at International Livestock Centre for Africa (ILCA), 31 August - 4 September 1987

Fayera A Muktar M, and Adugna D (2014): Effects of different rates of NPK and blended fertilizers on nutrient uptake and use efficiency of tef [Eragrostis Tef (Zuccagni) Trotter] in Dedessa Woreda, Southwestern Ethiopia. Journal of Biology, Agriculture and Healthcare 4(25):254-258

Griffiths G Trueman L Crowther T, Thomas B and Smith B (2002): Onions a global benefit to health. Phytother. Res. 16:603-615.

Gomez KA and Gomez AA (1984): Statistical procedures for agricultural research, 2nd edition. John Viley and Sons Inc., New York

Hailu DK Aklilu MM and Mikael TY (2015): An investigation on the influence of intra-row spacing and variety on yield and shelf life of onion. Int. J. Agric. Sci. 5(3):559-567.

Hanelt P (1990): Taxonomy, evolution, and history. In Onions and allied crops, edited by Haim D. Rabinowitch and James L. Brewster, 1-26. Boca Raton, Fla.: CRC Press.

Hazelton P and Murphy B (2007):Interpreting soil test results:What do all the numbers mean? 2nd Edition.CSIRO Publishing.Australia, 152p.

Marschner H (1995):Mineral nutrition of higher plants. 2nd Ed. Academic Press, New York., pp 674.

Mehoni Agricultural research center (2016): Anuall report of Mehoni Agricultural Research Center 2015/16, Maychew ,Tigray ,Ethiopia

Nimona Fufa, Girma Abera and Edossa Etissa (2018).Agronomic and economic performance of hot pepper (Capsicum annuum L.) in response to blended fertilizer supply at Asossa, Western Ethiopia. International Journal of Plant & Soil Science 26(2): 1-11.

SAS (Statistical Analysis System) Institute (2004). SAS user guides, version 9.1.SAS Inc. Cary. North Carolina, USA.

Solomon Fantaw, Derajew Asres and Aleminew Tagele (2019): Effect of blended chemical fertilizer (sulfur, nitrogen and phosphorus) on yield and yield components of potato (Solanum tuberosum L.) in the rainy season.Journal of Horticulture and Forestry 11(3):54-61

Tekalign Tadese (1991): Soil, plant, water, fertilizer, animal manure and compost analysis. Working document No.13. International Livestock Research Center for Africa, Addis Ababa, Ethiopia.

Blended Fertilization: a New Approach for Improving Onion Yield using NPSZnB Fertilizer at Mereb-Lekhe Woreda, Central Tigray, Ethiopia

Tsadik Tadele[1]*, Geberesemaeti Kahsu[1], Weldegebrel Gebrehiwet[1], Tewolde Berhe[1], Kinfe Tekulu[1], Tarekegn Yibabie[1], Solomon Mebrahtom[1], Samrawit Mebrahtu[1], Gidena Tasew[2]

[1] Tigray Agricultural Research Institute, Shire Soil Research Centre, P.O. Box 40, Shire, Ethiopia
[2]Tigray Agricultural Research Institute, Mekelle Soil Research Center, P.O. Box 1070, Mekelle, Ethiopia

*Correspondence: tsadiktadele27@yahoo.com

Abstract

Among the factors constraining crop production, applying unbalanced and suboptimal levels of mineral fertilizers are the foremost in the study area. Hence, field experiment was conducted at Mereb lekhe Woreda of Tigray Regional State, Northern Ethiopia under irrigation condition to examine the effect of blended NPSZnB fertilizer on onion during 2017 and 2018. The experiment comprised of eight blended NPSZnB fertilizer rates (0, 25, 50, 100, 150, 200, 250 and 300 kg NPSZnB ha^{-1}) and one blanket recommended NP rate (96 kg ha^{-1} N, 69 kg ha^{-1} P). The treatments were set in a randomized complete block design (RCBD) with three replications on 3 by 3m plot size. Accordingly, almost all the onion agronomic parameters were statistically influenced by the different blended NPSZnB fertilizer rates. Consequently, blended fertilizer comprising appropriate rates of all the deficient nutrients in the study area gave highest onion yield. Application of 100 kg ha^{-1} blended NPSZnB fertilizer was agronomicaly and economicaly profitable for onion production with 18.5% increment over the blanket recommendation. Therefore, application of blended NPSZnB fertilizer at a rate of 100 kg ha^{-1} plus 64 kg N ha^{-1} for onion is economically beneficial compared to the other blended fertilizer rates and that of blanket recommendation.

Keywords: Blended fertilizer, economic analysis, onion, marketable yield

Introduction

The Ethiopian agricultural sector employs about 80% of the population and generates over 42% of GDP and 70% of export earnings in 2014 (African Economic outlook 2015). It plays a significant role in improving food security in the near to mid-term [International Food Policy Research Institute (IFPRI), 2010]. The majority of Ethiopian farmers are small-scale producers and about 94% of them are estimated to rely on less than 5 ha of land, of which 55% cultivate less than 2 ha (Lulit et al 2016). Furthermore, only 5% of the country's agricultural land is irrigated, largely leaving agriculture to the fate of variable and poorly distributed rains (World Bank 2014).

Crop production is rapidly reducing due to the negative impact of various environmental stresses. More than 50% average yields of major crops are reducing primarily by abiotic stresses, whereby causes losses worth hundreds of millions of dollars each year (Mahajan and Tuteja 2005), and are becoming the major limiting factors for crop production especially under globally changing climatic conditions (Wang et al 2012). Continuous cropping, intensive land use (Corsky and Ndikwo 2008) and shortening of fallow periods, which are needed to restore and maintain soil productivity (Nweke 2016) reduced soil fertility and crop productivity. Between 2010 and 2014, crop productivity in Ethiopia remained very low relative to its potential yields, only averaged to 2.21 t ha^{-1}(World Bank 2014). This low productivity might be due to many factors including land degradation, small farm size, recurrent drought, poor farming technologies [Central Statistical Agency (CSA), 2014], weather, input price, changes in farming practices, amounts of fertilizers used, seed quality and use of irrigation (CSA 2018).

Cereals and vegetables are the major agricultural commodities on which Ethiopians depend for their daily consumption. Onion is the most widely consumed and indispensable to improve the taste and scent of the food we eat (CSA 2018). Despite its importance, onion yield and quality are affected by various factors, among which is low/excess mineral nutrition, poor irrigation schedule or rainfall (Jaleel et al 2007; Cheruth et al 2008). Improper utilization of fertilizers and growing unsuitable varieties under the different agro climatic conditions might also have contributed for low productivity of onion (Ghaffoor et al 2003). Fertilizer application is among the major practices to improve crop production and farm and households income. However, the extent to which fertilizers are used still differs considerably between various regions of the country.

Urea and di-ammonium phosphate (DAP) were the most commonly used chemical fertilizers considering that nitrogen (N) and phosphorus (P) were the major limiting nutrients for Ethiopian soils. Researchers have been conducting many studies on different agro-ecologies towards improvement of agricultural productivity using urea and DAP in Ethiopia. However, the Ethiopian Soil Information System (EthioSIS) indicated that Ethiopian soils lack about seven nutrients (N, P, potassium (K), sulfur (S),cupper (Cu), Zinc (Zn) and boron (B) in soil fertility assessment study conducted in different Woredas and Kebeles (EthioSIS 2013). According, the current study area soils were reported to be deficient in S, Zn, B nutrients besides N and P.

Different fertilizer materials would be required containing all or most of the nutrients required by crops to ensure balanced fertilizer use (Habte and Boke 2017). Therefore, applying blended fertilizers containing these deficient essential nutrients to the soil may resolve the problem that limit crop productivity. Onion growth and maximum bulb and dry matter yield were obtained with the application of NPK (Madan and Sandhu 1985; Singh 2000). Maize N use efficiency raised by providing S, Zn, B, and K which also increased yields by 40% over the standard N-P recommendation alone (Jhon 2000).

Based on the studies conducted on field conditions to fine-tune one best rate of N, P, K, and S, various blended fertilizers including micronutrients (NPS, NPSB, NPSZn, NPSZnB, NPKSZnB etc.) were formulated by EthioSIS (2014) for diverse agro-ecologies and soils. Afterwards, these blended fertilizers were verified for different Woredas according to their deficiency to recommend an area and crop specific blended fertilizer. However, the rates of blended fertilizers were not studied and identified for various crops. Hence, this study was conducted to determine and recommend site and crop specific blended NPSZnB fertilizer rates for optimum onion production under irrigation condition at Mereb Lekhe Woreda, Central Tigray, Northern Ethiopia.

Materials and Methods

Study area description

Study was carried out for two successive years at Hamedo irrigation scheme, Mereb Lekhe Woreda, Central Tigray, northern Ethiopia on two farmers' fields per year based on the soil fertility map developed by EthioSIS for the Woreda and Kebele. Hamedo irrigation scheme is found at around 50 km away to the north of Adwa town and 5 km away to the south of Rama town. Mereb Lekhe is surrounded by Tahtay Maichew, Laelay Maichew, Adwa and Ahferom Woredas and Eritrea on the west, southwest, southeast, east and northern, respectively. The study area is located between 14˚20'0" N and 38^{o}40'0" E to 14^{o}25'0" N and 38^{o}50' 0" E (Figure 1).

The major soil textural class of the study is characterized as sandy loam and loam. The study area mainly lies under semi-arid tropical belt of Ethiopia with a hot to warm agro-climatic zone with a mono-modal and erratic rainfall pattern. The moist growing period of the study area is laid in to three months of June to September.

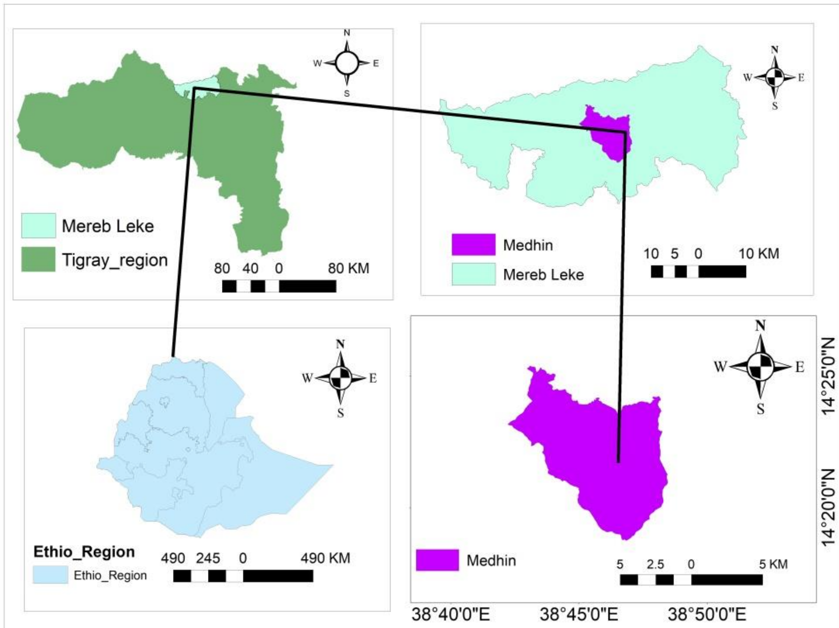

Figure 1: Location map of study area at Mereb Lekhe Woreda, Tigray, Ethiopia

Experimental design and treatments

The experiment consisted of seven treatments of which six treatments were blend (0, 25, 50, 100, 150, 200, 250 and 300 kg NPSZnB ha^{-1}) and while one treatment was blanket recommended fertilizer (96 kg ha^{-1} N, 69 kg ha^{-1} P) from DAP and urea. The 100 kg blended NPSZnB fertilizer contained 17N: 34 P_2O_5: 7S: 2.2Zn and 0.67 kg B ha^{-1}. The different blended NPSZnB fertilizer rates were compared among each other and against the blanket recommended NP fertilizer. The blended fertilizer rates and DAP were basal applied during transplanting the onion plants while the same amount of (64 kg N ha^{-1}) was top dressed 45 days after planting for all except the blanket recommended treatment. The test crop was also planted in rows. The other onion management practices were performed as per the recommendation.

The treatments were set in RCBD in three replications. The plot sizes was 3 m by 3 m (9 m^2) and the spacing between blocks, plots, ridges, plant rows and plants were also 1, 0.5, 0.4, 0.2 and 0.1 m, respectively. Improved onion variety (Bombay red) was used. This experiment was conducted for two consecutive seasons on two sites per year (2017/2018).

Soil data collection and analysis

One representative composite soil sample was taken at 0 to 30 cm depth before planting, from each farmer's fields using an auger. The collected samples were properly labeled, packed and transported to Shire Soil Research Center. Particle size distribution was determined using the Bouyoucos hydrometer method (Bouyoucos 1962). The pH of the soil was measured in the supernatant suspension of a 1: 2.5 soil to water ratio using a pH meter (Rhoades 1982). Electrical conductivity (EC) (1:25 soil to water suspension) was measured according to the method described by Jakson (1967). Ammonium acetate method was used to determine Cation exchange capacity (CEC) was Organic carbon (OC) was determined by the Walkely and Black (1934) method. Total N was determined using the Kjeldahl method as described by Bremner and Mulvaney (1982). Available P was determined following the Olsen method (Olsen et al 1954) using ascorbic acid as reducing agent.

Crop data collection and analysis

Agronomic data like marketable yield, single bulb weight, bulb diameter, bulb length, leaf length, leaf number per plant, plant height and days to 90% maturity and planting date were collected. The collected data were subjected to statistical analysis. Analysis of variance (ANOVA) was carried out using Statistical Analysis System (SAS). Significant difference between and among treatment means were assessed using the least significant difference (LSD) at 0.05 level of probability (Gomez and Gomez 1984).

Partial budget analysis

Partial budget analysis was performed to investigate the economic feasibility of the treatments. Partial budget, dominance, marginal and sensitivity analysis was used to test. The average yield was adjusted downwards to reflect the difference between the experimental plot yield and the yield farmers would expect from the same treatment. The average open market price (Birr kg^{-1}) for onion and the official prices of the balanced fertilizers were used for analysis. For a treatment to be considered a worthwhile option to farmers, the minimum acceptable rate of return (MRR) was considered to be greater than or equal to 100% [International Center for Maize and Wheat Research (CIMMYT), 1988], which is suggested to be realistic. The daily labor cost was supposed to be 60 ETB per person and revenue was estimated by considering the prevailing market price which was 18 ETB per kg of yield. Fertilizer cost for NPSZnB, urea and triple super phosphate (TSP) were also 1781.64, 1252 and 1855 ETB per 100 kg, respectively. The following formulas were used for the economic analysis:

Average marketable yield (MY) (kg ha^{-1}): is an average yield onion on each treatment

Adjusted yield (AjY): is the average yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers' field.

$$AjY = MY - (MY * 0.1)$$

Gross field benefit (GFB) or Total revenue (TR**)**: was computed by multiplying field/farm gate price that farmers receive for the crop when they sale it as adjusted yield.

$$TR = AjY * \text{field or farm gate price of a crop}$$

Total variable cost (TC): is the cost of inputs that were used for the experiment as mean current prices of the blended NPSZnB and other fertilizers, wage for fertilizers application and transport of fertilizers, and were considered per hectare.

Net revenue (NR): was calculated by subtracting the total costs from the total revenue (gross field benefit) for each treatment.

$$NR = TR – TC$$

Marginal rate of return: percent marginal rate of return was calculated as changes in net benefit (raised benefit) divided by changes in cost (raised cost).

$$MRR (\%) = (MB/MC)*100$$

Where; Marginal cost (MC) = change in costs between treatments and Marginal benefit (MB) = change in net benefits between treatments.

Results and Discussion

Selected soil physical and chemical properties of the study sites

Soils of the study areas at Mereb-Lekhe were characterized as sandy loam and sandy clay loam for 2017 and 2018 sites, respectively (Table 1). Soil bulk densities were 1.35 and 1.30 g cm^{-3} for the consecutive years. According to Hazelton and Murphy (2007), the soil of the study area was not restricting plant roots because a normal soil bulk density range is below 1.4 g cm^{-3}.

Table 1. Pre sowing selected physical and chemical soil properties of the study area

Soil properties	Year I		Year II	
	Values	Rating	Values	Rating
		Chemical properties		
pH (1:2.5 H_2O)	6.16	Slightly acid	7.28	Neutral
EC (dS m^{-1})	0.28	Low	0.85	Low
CEC (cmol(+) kg^{-1})	10.7	Low	20.6	Moderate
OC (%)	0.66	Low	0.94	Low
TN (%)	0.07	Medium	0.10	Medium
Olsen-P (mg kg^{-1})	4.21	Low	4.66	Low
Exc. K (cmol(+) kg^{-1})	0.35	Medium	0.45	Medium
		Physical properties		
Clay (%)	19		27	
Silt (%)	21	Sandy Loam	21	Sandy clay loam
Sand (%)	60		52	
Bulk density (g cm^{-3})	1.35	Not restricting plant roots	1.30	Not restricting plant roots

Where; EC= Electrical conductivity, CEC= Cation exchange capacity, OC= Organic carbon, TN= Total nitrogen, Olsen-P = Available phosphorus, and Exc. K= Exchangeable potassium.

The pH of the soils in the study area was observed to be slightly acidic and neutral for 2017 and 2018, respectively (Table 1) according to the rating of Tekalign (1991) while the electrical conductivity of the soils of both years indicated non-saline (Marx et al 1999). Generally, the soluble salts concentration of the study sites soil were below the critical levels at which most agricultural crops can grow and produce yield (Landon 1991). The soil OC and available P of the study sites for both years were low (Tekalign 1991; Olsen et al 1954). Total N and exchangeable K [Food and Agriculture Organization (FAO), 2006] were medium. This might be due to the addition of crop residues from the main season. The CECs were categorized as low and moderate for the year 2017 and 2018, respectively (Hazelton and Murphy, 2007). The moderate CEC of the soil for the II year site might be due relatively higher clay and OC contents than the year 2017.

Effects of NPSZnB fertilizer on phenology, growth parameter and yield of onion

Onion maturity was significantly ($P \leq 0.05$) influenced by the different NPSZnB fertilizer rates (Table 2). Onion maturity was hastened on most of the plots except the 50 kg NPSZnB ha^{-1} application rate. Plant height of onion was also significantly affected ($P \leq 0.05$) by blended NPSZnB fertilizer rates. The highest and lowest onion plant heights were 47.70 and 42.07cm, (Table 2) at the 0 NPSZnB and 250 NPSZnB kg ha^{-1} applications, respectively. These results are in line with the result of Faten et al (2010) who reported highest onion plant height due multi nutrients application, which revealed that the positive cumulative effects of more than two nutrients available in the compound fertilizers than the fertilizer containing single/two elements.

Table 2. Days to maturity, plant height, number of leaves per plant and leaf length of onion as influenced by blended NPSZnB fertilizer rate under irrigation condition, Mereb Lekhe Woreda

Treatments	DM (days)	PH (cm)	Leaf number	LL (cm)
Rec. NP (96 kg N ha^{-1}, 69 kg P ha^{-1})	118.00a	42.07b	11.73	35.27
0 NPSZnB (kg ha^{-1})	123.65c	40.33b	11.12	34.06
25 NPSZnB (kg ha^{-1})	119.00a	43.93ab	12.33	36.67
50 NPSZnB (kg ha^{-1})	121.00b	44.20ab	13.33	36.67
100 NPSZnB (kg ha^{-1})	118.67a	44.60ab	12.20	36.80
150 NPSZnB (kg ha^{-1})	118.33a	44.93ab	12.47	37.07
200 NPSZnB (kg ha^{-1})	119.33ab	43.60ab	13.00	35.53
250 NPSZnB (kg ha^{-1})	118.33a	47.47a	12.00	38.60
300 NPSZnB kg ha^{-1})	121.22b	45.33a	12.67	39.70
Mean	118.95	44.40	2.43	36.66
LSD ($_{0.05}$)	1.84	5.15	NS	NS
CV (%)	0.87	6.52	7.65	7.63

Where; DM= Days to maturity, PH= Plant height, and LL= Leaf length.*Urea was top dressed at equal level (150 kg ha^{-1}) for the blended fertilizer treatments.

Number of leaves per plant and leaf length of onion were not significantly ($P \leq 0.05$) affected by the different blended NPSZnB fertilizer rates. Although all rates were statistically at par, the highest number of leaves per plant and longest leaf were recorded from plots received 50 and 300 kg ha^{-1} blended NPSZnB fertilizer rate, respectively. On the other way, the lowest number of leaves per plant and shortest leaf were recorded on plots received 0 NPSZnB (Table 2). According to the current study, further increase in the blended fertilizer dose resulted in declining onion leaves. The highly growing plant vegetative parts like the leaf length are mostly related to N concentration which is in line with Kumar et al (1998) who reported that application of N at 150 kg ha^{-1} gave the best results with regard to leaf length.

Onion bulb length, bulb diameter and single onion bulb weight were not significantly ($P \leq 0.05$) affected by the different rates of blended NPSZnB fertilizer (Table 3). Highest onion single bulb weight was obtained in response to the 250 kg blended NPSZnB ha^{-1} fertilizer rate which might be due to the sufficient supply of the major limiting nutrients in the area. This might be because onion is a heavy nutrient feeder vegetable crop that requires more mineral fertilizer than other vegetables (Yohannes et al 2013). On the other hand, the lowest onion single bulb weight was recorded from plots received 100 kg NPSZnB ha^{-1} for the study area.

Yield of onion was significantly ($P \leq 0.05$) affected by the different rates of blended NPSZnB fertilizer. The result showed an increasing trend of onion yield with increased rate of applied blended NPSZnB fertilizer (Table 3). In line with the current study, Tsadik et al (2019) also reported onion yield improvement with increasing rate of applied blended NPSKZnB fertilizer. The highest marketable yield was recorded in response to the application of 250 kg ha^{-1} blended fertilizer as compared to the other rates and blanket recommended NP fertilizer. Though, it was not significantly different from the application of 250 kg ha^{-1}. In contrast, the lowest marketable yield was obtained in response to 0 kg ha^{-1} blended fertilizer. The finding of Assefa et al (2015) also revealed that using the optimum amount of fertilizer nutrients substantially increases the productivity of onion bulbs. The increased production of large dry matter and bulb weights of the crop that increased the total bulb yield might be due to interaction of the plant nutrients applied (Diriba Shiferaw 2017).

Table 3. Bulb length, bulb diameter, single bulb weight and marketable yield of onion as influenced by blended NPSZnB fertilizer rate under irrigation condition, Mereb Lekhe Woreda

Treatments(kg ha-^{1})	BL (cm)	BD (cm)	SB Wt (kg $bulb^{-1}$)	MY (kg ha^{-1})
Rec. NP (96 kg N ha^{-1}, 69 kg P_2O_5 ha^{-1})	3.77	5.60	0.373	20767b
0 NPSZnB	3.55	5.67	0.367	15634c
25 NPSZnB	4.27	6.00	0.407	22481ab
50 NPSZnB	4.07	6.00	0.383	24147ab
100 NPSZnB	4.00	5.53	0.358	24612a
150 NPSZnB	4.20	5.60	0.345	24884a
200 NPSZnB	3.80	6.20	0.373	25000a
250 NPSZnB	3.47	5.73	0.595	25698a
300 NPSZnB	3.88	5.65	0.454	20767b
Mean	3.94	5.81	4.04	23941.31
LSD ($_{0.05}$)	1.35	0.98	0.283	3415.30
CV (%)	19.23	9.43	19.4	8.02

Where; BL= Bulb length, BD= Bulb diameter, SB Wt= Single bulb weight, and MY= Marketable yield.*Urea was top dressed at equal level (150 kg ha^{-1}) for the blended fertilizer treatments

Partial budget analysis

The result of the current study showed that onion yield was significantly affected by the various rates of blended NPSZnB fertilizer. The maximum onion yield was recorded from plots treated with 250 kg NPSZnB ha^{-1} (Table 4). Likewise, economically profitable onion yield was also obtained in response to that specific rate according to the partial budget analysis (Table 4). Thus, application of 250 kg ha^{-1} blended NPSZnB fertilizer for onion is agronomical and economically beneficial compared to the other blended fertilizer rates and the blanket recommendation.

Conclusion and Recommendation

Various blended NPSZnB fertilizer rates significantly affected some onion agronomic parameters. The onion marketable yield showed increasing trend with an increase in blended fertilizer rates. Compared to the blanket recommended NP fertilizer, onion yield is higher when blended fertilizer is applied.

The highest mean marketable yield was obtained in response to 250 kg ha^{-1} blended application, though it was not significantly different from application of 100 kg ha^{-1}. The 100 kg ha^{-1} showed 18.5% and 57% onion yield improvement over the blanket fertilizer recommendation and control (0 kg ha^{-1}) blended fertilizer, respectively. In conclusion the blended NPSZnB fertilizer improves the yield and yield component of onion by supplying the deficient nutrients within the blending. The blended NPSZnB fertilizer rate of 100 kg ha^{-1} resulted in statistically higher onion yield and was also found to be economically profitable for optimum onion production at the Mereb-Leke Woreda. Therefore, based on the results of the study it can be recommended that farmers shall use the blended NPSZnB fertilizer in their cropping system since it improves onion production and productivity. This type of blended fertilizer shall be used at a rate of 100 kg ha^{-1} for onion production under irrigation condition at Mereb-Lekhe Woreda. For further study researchers can use the rate as a bench mark. Crop growth and production is affected by the most limiting nutrient. Therefore, similar studies shall be carried out based on deficient nutrients and crop specific conditions.

Table 4. Partial budget analysis of blended NPSZnB fertilizer for onion at Mereb-Lekhe Woreda

Fertilizer rates (kg ha^{-1})	FC (Birr)	TLC [Birr]	TVC [Birr]	MY (kg/ha)	AjY (kg/ha)	TR [Birr]	NR [Birr]	MRR (ratio)	MRR (%)
0 NPSZnB (kg ha-^{1})	0	0	0	15634	14070.6	253270.8	253271	0	0
25 NPSZnB (kg ha-^{1})	445.41	30	475.41	22481	20233	364192	363717	232.32	23232
50 NPSZnB (kg ha-^{1})	890.82	60	950.82	24147	21732	391181	390231	55.77	5577
100 NPSZnB (kg ha-^{1})	1781.64	120	1901.64	24612	22151	398714	396813	6.92	692
150 NPSZnB (kg ha-^{1})	2672.46	150	2822.46	24884	22396	403121	400268	3.63	363
200 NPSZnB (kg ha-^{1})	3563.28	210	3773.28	25000	22500	405000	401197	0.98	98
250 NPSZnB (kg ha-^{1})	4454.1	270	4724.1	25698	23128	416308	411554	10.89	1089
Rec. NP (96 N, 69 P kg ha^{-1})	4660.5	330	4990.50	20767	18690	336425	331435	D	D
300 NPSZnB (kg ha-^{1})	5344.92	330	5674.92	20767	18690	336425	330750	D	D

Where; FC= Fertilizer cost, TLC= transport and labor cost, TVC= Total variable cost, MY= marketable yield, AjY= Adjusted yield, TR= Total Revenue, NR= Net revenue and MRR= marginal rate of return.

References

Abdul Ghaffoor, Muhammad Saleem Jilani, Ghulam Khaliq and Kashif Waseem (2003): Effect of different NPK levels on the growth and yield of three onion (Allium cepa L.) varieties. Asian *J. Plant Sci* 2(3): 342-346.

African Economic Outlook (2015): Regional Development and Spatial Inclusion: www.africaneconomicoutlook.org; Thematic Edition.

Assefa AG Mesgina SH and AbrihaYW (2015): Effect of inorganic and organic fertilizers on the growth and yield of garlic crop (*Allium sativum L*.) in Northern Ethiopia. *J Agric Sci* (7):80.

Baloch MA Baloch AF Baloch G Ansari AH and Qayyum SM (1991): Growth and yield response of onion to different nitrogen and potassium fertilizer combination levels. Vegetable crops. *In*: Bashir E and Bantel R (eds) Horticulture. National Book foundation Islamabad Pakistan, pp: 501.

Bouyoucos J (1962): Hydrometer method improved for making particle size analysis of soil. *Agronomy Journals* (54): 464-465.

Cheruth J Ragupathi G Ashot K Paramasiveam M Beemarao S Rajaram P (2008): Interactive effects of triadimefon and salt stress on antioxidantive status and ajmalicine accumulation in Catharan thusroseus. *Acta Physiol. Plant* 30(3), pp. 287-292.

CIMMYT (International Center for Maize and Wheat Research) (1988):.from Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely Revised Edition, Mexico, DF.79 pp.

Corsky RJ Ndikawa R (2008). Screening multiple use cover crops for the Sudan Savannah of N/Cameroon D Bukies Canada. pp. 79-187.

CSA (Central Statistical Agency) (2014): Comprehensive food security and vulnerability analysis.The Federal Democratic Republic of Ethiopia.

CSA (Central Statistical Agency) (2018): Agricultural sample Survey, Report on Area and Production of Major Crops.

Diriba Shiferaw G (2017): Comparative Study of Different Compound Fertilizers on Garlic (*Allium Sativum* L.) Productivity under Various Soils and Seasons. *Global Journal of Science Frontier Research: D Agriculture and Veterinary* 17(1), Version (1).

Dogliotti SK Giller E and Van Ittersum MK (2014): Achieving global food security whilst reconciling demands on the environment: Report of the First International Conference on Global Food Security. *Food Security* 6 (2):299–302.

EthioSIS (Ethiopian soil information system) (2013). Soil analysis report agricultural transformation agency. DOI: http://dx.doi.org/10.1080/00103624.2016.1166378.

EthioSIS (Ethiopian Soil Information System) (2014): Soil Fertility Status and Fertilizer Recommendation Atlas for Tigray Regional State, Ethiopia. July 2014. Ministry of Agriculture and Agricultural Transformation Agency: 92. www.ata.gov.et.

FAO (Food and Agriculture Organization) (2006): Guidelines for soil description. 4th edition. Rome

Faten SA Shaheen El-Al Fatma AM Rizk A and Hafez MM (2010): Influence of irrigation intervals and potassium fertilization on productivity and quality of onion plant. *Int. J. Acad. Res.* 2:110-116.

Gomez and Gomez H (1984): Statistical analysis for agricultural research. John Willy and Sons Inc. pp: 120-155.

Haile W Boke S (2011) Response of Irish Potato (Solanumtuberosum) to the Application of Potassium at Acidic Soils of Chencha, Southern Ethiopia. *International Journal of Agricultural Biology* (13):595-598.

Hazelton P. and Murphy B (2007): Interpreting soil test results: What do all the numbers mean? 2nd Edition.CSIRO Publishing. 152p.
IFPRI (Fertilizers and Soil Fertility Potential in Ethiopia) (2010): Fertilizers and Soil Fertility Potential in Ethiopia: Constraint and Opportunities for Enhancing the System. IFPRI, Washington.
Jaleel CA Manivannan P Sankar B Kishorekumar A Gopi R and Somasundaram R (2007): Water deficit stress mitigation by calcium chloride in Catharanthusroseus: Effects on oxidative stress, proline metabolism and indole alkaloid accumulation. *Colloids Surf B Biointerfaces* (60): 110-6.
John IH Mayorga E Tsamakis E McClain ME Aufdenkampe A and Quay P (2000). Organic matter in Bolivian tributaries of the Amazon River: A comparison to the lower mainstream, Limnol. American Society of Limnology and Oceanography, Inc.,Washington, 45(7):1449-1466.
Kumar H Singh JV Ajay K Mahak S Kumar A and Singh M (1998): Studies on the influence of nitrogen on growth and yield of onion Cv. Patna Red. *Indian J. Agric. Res*. (32): 88-92.
Landon JR (1991): Booker Tropical Soil Manual: A hand book for soil survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical, Essex, New York.474p. OR John Wiley & Sons Inc., New York.
Lulit Mitik, Bekele Shiferaw, Amarendra Sahoo and Sika Gbegbelegbe (2016): Economy-wide impacts of technological change in food staples in Ethiopia: A macro-micro approach. Working paper 2016-17.
Madan SPS and Sandhu JS (1985) Influence of nitrogen, phosphorus and potash levels on the growth, bulb yield and dry matter production of white onion variety. Punjab-48 Punjab Veg. Grower, 20; 17-24.
Mahajan S Tuteja N (2005): Cold, salinity and drought stresses: an overview. *Archives of Biochemistry and Biophysics* (444): 139–158.
Marx J Hart and Stevens RG (1999): Soil Test Interpretation Guide. Oregon State University Extension Service, EC 1478.
Mulugeta Habte ansd Shiferaw Boke (2017): Influence of balanced nutrients on growth performance and yield of Tef (Eragrostis tef (Zucc.)) in the midland of Bensa, Southern Ethiopia. *Journal of Scientific and Innovative Research* 6(3):101-103. www.jsirjournal.com
Nweke IA (2016): Influence of different leguminous crop on the ultisol that had been continuously cropped to cassava /maize for over six years. *J. Soil Sci. Environ. Manage* 7(12): 222-229. DOI: 10.5897/JSSEM2016.0555.
Olsen R Cole S Watanabe F and Dean L (1954): Estimation of available phosphorus in soils by extraction with sodium bicarbonate.*United States Department of Agriculture* Circ. 939.
Rhoades JD (1982): In Methods of Soil Analysis, Part 2.Second Edition (A.L. Page.Miller and D.R. Keeney, Eds.), American Society of Agronomy. Madison, USA.
Simon T Tora M Shumbulo A and Urkato S (2015): The effect of variety, nitrogen and phosphorus fertilization on growth and bulb yield of onion (Allium cepa L.) at Wolaita, Southern Ethiopia. *J Biol, Agric Healthcare* 4: 90-92.
Singh RP Jam NK and Poonia BL (2000): Response of Kharif onion to nitrogen, phosphorus and potash in eastern plains of Rajasthan. *Indian J. Agri. Sci* 70; 871-872.
Statistical Analysis Software (SAS) (2002): SAS Institute Inc., Cary, NC, USA. SAS (r) Proprietary Software Version 9.00 (TS M0), Licensed to SUNY AT STONY BROOK, Site 0013402001.
Stefen WK Richardson J Rockström SE Cornell I Fetzer EM Bennett R Biggs SR Carpenter W. De Vries CA De Wit C Folke D Gerten J Heinke GM Mace LM Persson V Ramanathan B Reyers and Sörlin S (2015) Planetary boundaries: Guiding human development on a changing planet. *Science* 347:6223.

Tekalign Tadese (1991) Soil, plant, water, fertilizer, animal manure and compost analysis.Working Document No.13.International Livestock Research Center for Africa, Addis Ababa.

Tsadik Tadele, Tewolde Berhe, Tarekegn Yibabie, Kinfe Teklu, Gebresemaeti Kahsu, Weldegebrel Gebrhiwer, Solomon Mebrahtom and Samrawit Mebrahtu. (2019): Effect of NPSKZnB blended fertilizer on yield and yield components of onion (Allium cepa) in Northen Western Tigray, Ethiopia. *In:* Tesfay Belay, Bereket Haileselassie, Teferi Aregawi, Tsegay Gebreselassie, Haftu Kelelew and Desalegn Emiru (eds), 2019. Workshop Proceeding for Completed Research Activities on Adaptation and Generation of Agricultural Technologies, 09-15 November 2018, Capital Hotel, Wukro, Ethiopia. Tigray Agricultural Research Institute and Agricultural Growth Program-II, Mekelle, Ethiopia.

Tilman DC Balzer J Hill and Befort BL (2011): Global food demand and the sustainable intensification of agriculture. Proceedings of the National Academy of Sciences of the United States of America 108 (50):20260–64.

Walkley A and Black IA (1934). An examination of the Degtjareff method for determining soil organic matter and proposed chromic acid titration method. *Soil Science*, (37):29-38.

Wang Y Zang J Sun Y Ali J Xu J and Li Z (2012) Identification of genetic overlaps for salt and drought tolerance using simple sequence repeat markers on an advanced backcross population in rice. *Crop Science* 52: 1583–1592.

World Bank (2014):World Development Indicators. http://data.worldbank.org/.

Yohannes KW Belew D and Debela A (2013). Effect of farmyard manure and nitrogen fertilizer rates on growth, yield and yield components of onion (Allium cepa L.) at Jimma, Southwest thiopia. *Asian J Plant Sci* 12: 228.

Blended Fertilization: New Approach for Improving Tomato Production using NPSZnB Fertilizer under Irrigation condition at Mereb lekhe Woreda, Central Tigray, Ethiopia

Tsadik Tadel[1]*, Geberesemaeti Kahsu[1], Weldegebrel Gebrehiwet[1], Tewolde Berhe[1], Kinfe Tekulu[1], Tarekegn Yibabie[1], Solomon Mebrahtom[1], Samrawit Mebrahtu[1], Gidena Tasew[2]

[1,] Tigray Agricultural Research Institute, Shire Soil Research Centre, P.O. Box 40, Shire, Ethiopia;
[2,] Tigray Agricultural Research Institute, Mekelle Soil Research Center; Mekelle, Tigray, Ethiopia

*Correspondence author: tsadiktadele27@yahoo.com

Abstract

The declining soil fertility status; mostly essential nutrient deficiencies and applying low level of fertilizers might cause the yield reduction. Therefore, study was started at Hamedo irrigation scheme, Mereb lekhe Woreda to investigate the effect and to determine rate of blended NPSZnB fertilizer for optimum tomato production and to develop site and crop specific fertilizer recommendation. Seven blended NPSZnB fertilizer rates (25, 50, 100, 150, 200, 250, 300 kg NPSZnB ha^{-1}) and blanket recommended NP fertilizer (96 kg ha^{-1} nitogen (N), 69 kg ha^{-1} P_2O_5) were tested in the experiment. All the treatments were set in a randomized complete block design (RCBD) replicated three times. Tomato yield responded to the blended NPSZnB fertilizer that is recommended for the study area compared to the blanket recommendation. Under irrigation condition, tomato total and marketable yield were high in plots that received 300 kg ha^{-1} blended NPSZnB fertilizer rate which might be due to the balanced nutrient levels in the blended fertlizer. Partial budget analysis revealed that~~,~~ economically profitable tomato yield was also attained in response to 300 kg ha^{-1} NPSZnB. Thus, compared to the other blended fertilizer rates and the blanket recommendation, producers may apply 300 kg ha^{-1} blended NPSZnB fertilizer rate for tomato production.

Keywords: Balanced fertilization, economic profitability, marketable yield, tomato

Introduction

Ethiopian agriculture is by large subsistence [Cental Statistical Agency, CSA 2018] in which crops and livestock represent an important means of survival for a significant part of the population (Alemayehu et al 2011). Within agriculture, cereals and other staple crops played a greater role in reducing poverty and increasing growth than other sectors in Ethiopia (Diao and Pratt 2007). The major agricultural commodities on which Ethiopians depend for their daily consumption are vegetables and cereal crops. Tomato is amongst the widely growing and promising freights in horticultural expansion and development in Ethiopia.

Smallholder farmers have grown tomato for their livelihood needs since the start of its commercialization (Ketema et al 2015). Tomato has the potential for development to a high value crop (Karuku et al 2017) having its productivity which is estimated at 33.6 tons ha^{-1} (FAO 2006). Average tomato yield in Ethiopia is however remained low ranging from 6.5-24 Mt ha^{-1} (Gemechis et al 2012) as compared with average yields of 51, 41, 36, and 34 Mg ha^{-1} in America, Europe, Asia and the whole world, respectively [FAOSTAT (FAO Statistical Databases) 2010]. This yield reduction might be due to a myriad barriers, like abiotic (high temperature, erratic rainfall, poor soils fertility, etc.) and biotic (pests, diseases etc.) factors (Willis et al 2019).

Key among the constraints that prevent farmers from achieving potential tomato yield might be low soil fertility, post-harvest losses and the lack of appropriate cultural practices (Ogbomo 2011). Depletion of soil nutrients and soil degradation from erosion and soil compaction might also threatens crop yields (Hamza and Anderson 2005; Taddesse 2001). Therefore, soil fertility maintenance is a major concern in the region to improve agricultural production in order to feed the growing population. In intensive agricultural systems, soil fertility can be maintained through applications of organic materials, inorganic fertilizers, lime, and the inclusion of legumes in the cropping system, and combination of some of these (Pandey et al 2006; Singh et al 2007).

In Ethiopia, farmers have been producing different crops using the blanket recommended fertilizers urea and di-ammonium phosphate (DAP) (Feyera et al 2014). Nevertheless, crop production remained low compared to their potential yields, which might be due to the deficiency of essential nutrients other than N and phosphorus (P) (EthioSIS 2013). This is because, crop growth, nutrient use efficiency, productivity and production is affected by the most limited nutrient. According to Feyera et al. (2014) crop nutrient uptake is high in plots with blended fertilizer. Haile and Boke (2011) also reported potato fertilizer use efficiency raised when NP fertilizers are combined with potassium (K) whereby tuber yield was increased by 197% over the standard NP recommendation alone. Hence, applying blended fertilizers comprised of the different mineral elements like N, P, K, Zinc (Zn), sulfur (S) and boron (B) etc. that are deficient in the study area should be used than only DAP and urea (Feyera et al 2014).

The previous fertilizer recommendation that was being practiced had to be revised according to the ground problems and nutrient deficiencies to solve the low crop productivity. Recently, different blended fertilizers consisting of the deficient macro and micronutrients were developed by EthioSIS (2014) in accordance to the results from various on farm studies conducted to refine optimum N, P, K, and S rates and soil fertility survey by EthioSIS (2013) for diverse agro-ecologies and soils. Then after, validations of the different blended fertilizers on different Woredas for which they were formulated were conducted and a blended NPSZnB fertilizer was recommended for Mereb lekhe Woreda. However, the rates of these blended fertilizers required for an optimum crop yield were not yet determined. Therefore, the present study was initiated to investigate the effect and to determine site and crop specific blended NPSZnB fertilizer rate recommendation for tomato production at Mereb lekhe Woreda.

Materials and Methods

Study area description

Field experiments were conducted during 2017 and 2018 at Hamedo irrigation scheme (Medhin kebelle), Mereb lekhe Woreda, Central Tigray Zone, Northern Ethiopia on two farmers' fields per year under irrigation condition following the soil fertility map developed by EthioSIS for the Woreda. The study area is mainly categorized under semi-arid with a hot to warm agro-climatic condition and a uni-modal and erratic rainfall pattern. Hamedo irrigation scheme is found at around 50 km away to the north of Adwa town and 5 km away to the south of Rama town. Mereb lekhe is surrounded by Tahtay maichew, Laelay maichew, Adwa, and Ahferom Woredas and Eritrea on the west, southwest, southeast, east and northern, respectively. The study area is located between 14˚22'25" N and 038°47'32" E to 14°38' 30" N and 38°56' 0" E (Figure 1).

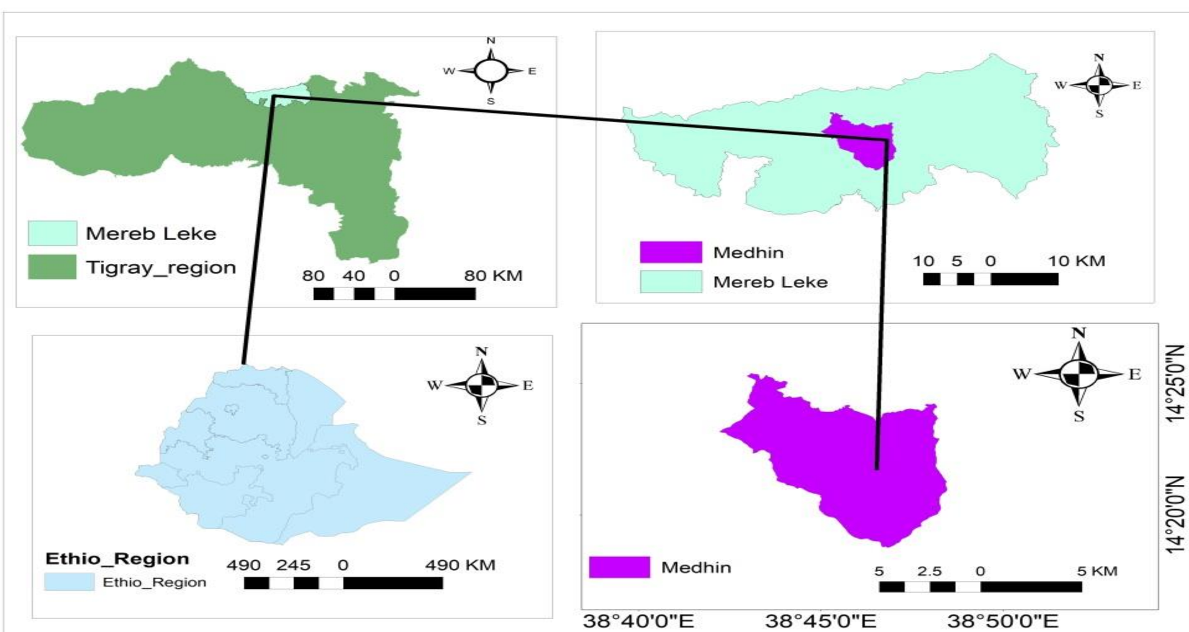

Figure 1. Location map of the study area at Mereb lekhe, Tigray, Ethiopia

The area mainly lies under semi-arid tropical belt of Ethiopia with a hot to warm agro-climatic zone with a uni-modal and erratic rainfall pattern. The moist growing period of the area is laid in to three months of June and September.

Experimental design and treatments

The experiment had seven levels of NPSZnB (0, 25, 50, 100, 150, 200, 250 and 300 kg NPSZnB ha^{-1}) and blanket recommended fertilizer (96 kg ha^{-1} N, 69 kg ha^{-1} P_2O_5) from DAP and urea. The blended fertilizer rates and DAP were applied when transplanting the tomato while the same amount of (64 kg N ha^{-1}) was top dressed 45 days after planting for all the treatments except the blanket recommended treatment. The test crop was also planted in rows. Tomato agronomic management practices were performed as per the recommendation.

The treatments were set in a randomized complete block design (RCBD) with three replications. The plot sizes was 3 by 3 m (9 m^2) and the spacing between blocks, plots, rows and plants were also 100, 50, 70, and 30cm, respectively. Improved onion variety (*Melka sholla*) was used. This experiment was conducted during 2017 and 2018 at two farmers' fields each year.

Crop data collection

Days to first maturity, plant height and yield (marketable, unmarketable and total yield) of the tomato were recorded and collected following standard procedures.

Economic analysis

Economic analysis was performed to investigate the economic feasibility of the treatments. Partial budget, dominance, marginal were carried out. The average yield was also adjusted downwards to reflect the difference between the experimental plot yield and the yield farmers would expect from the same treatment. The average open market price (Birr kg^{-1}) for different crops and the official prices of the balanced fertilizers were used for analysis. For a treatment to be considered a worthwhile option to farmers, the minimum acceptable rate of return (MRR) should be 100% [International Center for Maize and Wheat Research (CIMMYT), 1988] which is suggested to be realistic. This enables to make farmer recommendations from marginal analysis.

Result and Discussion

Growth parameters

Days to physiological maturity

Days to physiological maturity of tomato under irrigation condition was not statistically significantly ($P \geq 0.05$) affected by different NPSZnB fertilizer rates at Mereb lekhe Woreda. The first tomato maturity was delayed equally for the plots received 250 and 300 kg NPSZnB ha^{-1} rates in the study area (Table 1). The delayed tomato maturity in plots with high fertilizer rates might be due to the sufficient irrigation water and nutrient supply throughout the growing period which helped it to grow.

Table 1. Days to first maturity and plant height of tomato as influenced by blended NPSZnB fertilizer rates under irrigation condition

Treatments	DM (days)	PH (cm)
Rec. NP (96 kg N ha^{-1}, 69 kg P ha^{-1})	69.67	45.77^{bc}
25 NPSZnB (kg ha^{-1})	68.00	43.90^{c}
50 NPSZnB (kg ha^{-1})	68.50	50.17^{abc}
100 NPSZnB (kg ha^{-1})	67.83	51.63^{ab}
150 NPSZnB (kg ha^{-1})	68.67	53.43^{a}
200 NPSZnB (kg ha^{-1})	70.33	51.23^{abc}
250 NPSZnB (kg ha^{-1})	69.00	51.13^{abc}
300 NPSZnB (kg ha^{-1})	70.33	51.47^{ab}
Mean	69.04	49.84
LSD ($_{0.05}$)	NS	7.39
CV (%)	22.38	12.69

Where; Where; DM= days to maturity, PH= Plant height, and LSD= Least significant difference and CV= coefficient of variance.

Plant height

The analysis of variance revealed that tomato plant height was statically significantly affected ($P \leq 0.05$) by the different rates of NPSZnB blended fertilizer in the study area. This result is in consistent with that of Edossa et al (2013) who reported that application of N and P fertilizers had significant effect on plant height of tomato. The highest tomato plant height was 53.43 cm, whereas the shortest was 43.90 cm (Table 1). Though in statistical parity with some of the treatments, highest plant height was recorded from the application of 150 kg ha^{-1} blended NPSZnB fertilizer, while the shortest plant height was recorded on plots received 25 kg ha^{-1} NPSZnB.

Marketable yield

Tomato yield was statically significantly ($P \leq 0.05$) affected by the different rates of blended NPSZnB fertilizer at Mereb lekhe Woreda. The current study was in line with the report of (Singh 1978; Ahmad and Butt 1999) who indicated that significant yield increase was observed in tomato grown on NK and

NP treated soils, respectively. With some inconsistent trends, yield improvement was observed with increasing rate of applied blended fertilizer (Table 2). The highest marketable yield was recorded in response to the application of 300 kg ha^{-1} NPSZnB blended fertilizer. Lowest marketable yield (20194 kg ha^{-1}) was also obtained in response to the 25 kg ha^{-1} NPSZnB, which is the lowest blended fertilizer rate.

Table 2. Marketable, unmarketable and total yields of tomato as influenced by blended NPSZnB fertilizer rates under irrigation condition

Treatments	MY (kg ha^{-1})	UMY (kg ha^{-1})	TY (kg ha^{-1})
Rec. NP (96 kg N ha^{-1}, 69 kg P ha^{-1})	24241^{bc}	1556^{ab}	25796^{bc}
25 NPSZnB (kg ha-^{1})	20194^{c}	1328^{b}	21522^{c}
50 NPSZnB (kg ha-^{1})	32593^{ac}	2459^{ab}	35052^{ab}
100 NPSZnB (kg ha-^{1})	27056^{abc}	1909^{ab}	28965^{abc}
150 NPSZnB (kg ha-^{1})	30306^{ab}	2696^{a}	33002^{ab}
200 NPSZnB (kg ha-^{1})	31944^{ab}	2143^{ab}	34087^{ab}
250 NPSZnB (kg ha-^{1})	26778^{abc}	1991^{ab}	28769^{ab}
300 NPSZnB (kg ha-^{1})	33963^{a}	2626^{a}	36589^{a}
Mean	28384.26	2088.43	30472.69
LSD ($_{0.05}$)	9109.2	1171.20	9744.80
CV (%)	27.46	47.98	27.36

Where; MY= marketable yield, UMY= unmarketable yield, TY= total yield, and LSD= Least significant difference and CV= coefficient of variance.

Unmarketable yield

The analysis of variance showed that tomato unmarketable yield was significantly ($P \leq 0.05$) affected by the varying rates of NPSZnB fertilizer under irrigation condition. The highest unmarketable yield (2696 kg ha^{-1}) was obtained in response to the NPSZnB blended fertilizer rate of 150 kg ha^{-1} whereas, the lowest (1328 kg ha^{-1}) was from plots received 25 kg NPSZnB ha^{-1} rate (Table 2).

Total yield

According to the analysis of variance tomato total yield was statically significantly ($P \leq 0.05$) affected by the different NPSZnB fertilizer rates at the study area. Similar to the marketable yield highest total yield (36589 kg ha^{-1}) was obtained in response to the 300 kg NPSZnB ha^{-1} fertilizer rate (Table 2).

Economic analysis

According to the undertaken marginal rate of return analysis, 300 kg NPSZnB ha^{-1} was economically profitable rate at Mereb lekhe Woreda (Table 3). Thus, producers may apply 300 kg ha^{-1} NPSZnB fertilizer rate for optimum tomato yield compared to the other rates and blanket recommendation.

Table 3. Partial budget analysis of blended NPKSZnB fertilizer for tomato in Mereb lekhe Woreda

Fertilizer rate (kg ha^{-1})	FC (Birr)	TLC [Birr]	TVC [Birr]	MY (kg ha^{-1})	AjY (kg ha^{-1})	TR [Birr]	NR [Birr]	MRR (ratio)	MRR (%)
25 NPSZnB (kg ha^{-1})	445.41	30	475.41	20194	18175	327143	326667	0	0
50 NPSZnB (kg ha-^{1})	890.82	60	950.82	32593	29334	528007	527056	421.506	42150.6
100 NPSZnB (kg ha-^{1})	1781.64	120	1901.64	27056	24350	438307	436406	D	D
150 NPSZnB (kg ha-^{1})	2672.46	150	2822.46	30306	27275	490957	488105	D	D
200 NPSZnB (kg ha-^{1})	3563.28	210	3773.28	31944	28750	517493	513690	D	D
250 NPSZnB (kg ha-^{1})	4454.1	270	4724.1	26778	24100	433804	429050	D	D
Rec. NP (96 N, 69 P kg ha^{-1})	4660.5	330	4990.50	24241	21817	392704	387714	D	D
300 NPSZnB (kg ha-^{1})	5344.92	330	5674.92	33963	30567	550201	544526	3.69804	369.804

Where; FC= Fertilizer cost, TLC= transport and labor cost, TVC= Total variable cost, MY= marketable yield, AjY= Adjusted yield, TR= Total Revenue, NR= Net revenue and MRR= marginal rate of return.

Conclusion and Recommendation

Farmers in the study area have been applying fertilizers for their vegetable crops which were the blanket recommendation containing only N and P. The blanket recommended fertilizers were developed for the whole country regardless of the difference in agro-ecologies, soil and crop types. From the newly introduced blended fertilizers to the Woreda NPSZnB is one of them. This study revealed that the blended NPSZnB fertilizer improved the yield and yield component of tomato due to the fulfillment of the deficient nutrients in the blending. The 300 kg NPSZnB ha^{-1} rate resulted in higher tomato yields. However, economically the blended NPSZnB fertilizer at rates of 50 kg ha^{-1} was found to be profitable for tomato. Since the blended NPSZnB fertilizer improved tomato production and productivity farmers should use in their cropping system. Similar studies should be carried out based on deficient nutrients and crop specific conditions because crop growth and production is affected by the most limiting nutrient.

Reference

Alemayehu Seyoum Taffesse, Paul Dorosh and Sinafikeh Asrat (2011): Crop production in Ethiopia: Regional Patterns and Trends. Development Strategy and Governance Division, International Food Policy Research Institute, Ethiopia Strategy Support Program II, Ethiopia (ESSP II); ESSP II Working Paper No. 0016.

Alfred E and Hartemink (2003): Soil fertility decline in the Tropics: Case Studies on Plantations. CAB International.

Alfred Hartemink E (2002): Soil science in tropical and temperate regions–some differences and similarities. Advances in Agronomy77, 269–292.

Belachew T and Abera Y (2010): Assessment of soil fertility status with depth in wheat growing highlands of Southeast Ethiopia. World J. Agric. Sci. 6(5):525-531.

CIMMYT (International Center for Maize and Wheat Research), (1988): from Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely Revised Edition, Mexico, DF.79 pp.

CSA (Central Statistical Agency), (2018): Agricultural sample survey, report on area and production of major crops.

Diao X and Pratt AN (2007): Growth options and poverty reduction in Ethiopia- An economy-wide model analysis. Food Policy. 32(2):205-228.

Edossa Etissa, Nigussie Dechassa, Tena Alamirew, Yibekal Alemayehu and Lemma Desalegn (2013): Growth and yield components of tomato as Influenced by nitrogen and phosphorus fertilizer applications in different growing seasons. Ethiop. J. Agric. Sci.23:57-77.

EthioSIS (Ethiopian soil information system) (2013): Soil analysis report agricultural transformation agency. DOI: http://dx.doi.org/10.1080/00103624.2016.1166378.

EthioSIS (Ethiopian Soil Information System) (2014): Soil Fertility Status and Fertilizer Recommendation Atlas for Tigray Regional State, Ethiopia. July 2014. Ministry of Agriculture and Agricultural Transformation Agency: 92. www.ata.gov.et.

FAO (Food and Agriculture Organization) (2006): Food and Agriculture Organization. FAO Statistic Division, Rome.

FAOSTAT [Food and Agriculture Organization Statistical Database (2010)]: The food and agriculture organization of the United Nations statistical database: Romen farming. http://faostat.fao.org/default.aspx?lang=e.

Fayera Asefa, Muktar Mohammed and Adugna Debela (2014): Effects of different rates of NPK and blended fertilizers on nutrient uptake and use efficiency of tef [Eragrostis Tef . Journal of Biology, Agriculture and Vol.4, No.25. Healthcare . (Zuccagni) Trotter] in Dedessa Woreda, Southwestern Ethiopia.

Gemechis AO, Struik and B Emana (2012): Tomato production in Ethiopia: Constraints and opportunities. http://www.tropentag.de/2012/abstracts/full/659.pdf.

Gete Z, Getachew A, Dejene A and Shahid R (2010): A Report on fertilizer and soil fertility.

Giday O, Gibrekidan H, Berhe T (2014): Response of tef (Eragrostis tef) to different rates of slow release and conventional urea fertilizers in Vertisols of Southern Tigray, Ethiopia. Adv Plants Agric Res.;1(5):190–197. DOI: 10.15406/apar.2014.01.00030.

Haile W and Boke S. (2011): Response of Irish potato (Solanum tuberosum) to the application of potassium at acidic soils of Chencha, southern Ethiopia. International Journal of Agricultural Biology; 13:595-598.

Hamza MA and Anderson WK (2005): Soil compaction in cropping systems: A review of the nature, causes and possible solutions. Review Article. Soil and Tillage Research 82 (2): 121–145.

Karuku GN, Kimenju JW and Verplancke H (2016): Farmers' perspectives on factors limiting tomato production and yields in Kabete, Kiambu County, Kenya, East African Agricultural and Forestry Journal, 82:1, 70-89. http://dx.doi.org/10.1080/00128325.2016.1261986.

Ketema Balcha, Derbew Belew and Jima Nego (2015): Evaluation of tomato (Lycopersicon esculentum Mill.) varieties for seed yield and yield components under Jimma condition, south western Ethiopia. Journal of Agronomy 14 (4): 292-297, ISSN 1812-5379. DOI: 10.3923/ja.2015.292.297.

Mureithi JG, Mwaura PM and Nekesa CO (2000) Introduction of legume cover crops to smallholder farms in Gatanga, Central Kenya. In: Proceedings of the Second Scientific Conference of the Soil Management and Legume. Research Network Projects; p. 98–102.

Ogbomo KE (2011): Comparison of growth, yield performance and profitability of tomato (Solanum lycopersicon) under different fertilizer types in humid forest ultisols. http://www.interesjournals.org/full-articles/comparison-ofgrowth-yield-performance-and-profitability-oftomato-solanum-lycopersiconunder-different- fertilizer-types-in-humid-forest-ultisols.

Pandey CB, Sharma DK and Bargali SS. (2006). Decomposition and nitrogen release from Leucaena leucociphala in Central India. Tropical Ecology. 47(1):149-151.

Shamshad Ahmad and Shahid Javed Butt (1999): Effect of NPK on some yield components of tomato (Lycopersicon Esculentum Mill.). ANADOLU, J. of AARI 9 (1) 56 - 62 MARA.

Singh SP Shrivastava SK Kolhe SS Patel JR and Bargali SS (2007): Prospects of biofertilizers and organic manure utilization: a case study from Durg Woreda. Agric. Res. Digest. 27(3):157-161.

Singh K (1978): Manurial requirements of vegetables. Indian Council of Agric. Res. New Delhi. p. 64.

Taddesse G (2001): Land degradation: A challenge to Ethiopia. Environmental Management 27 (6): 815–824.

Willis N, Ochilo Gideon. Nyamasyob N, Dora Kilalo, Washington Otieno, Miriam Otipa, Florence Chege, Teresia Karanja, Eunice, Lingeera K (2019): Characteristics and production constraints of smallholder tomato production in Kenya. Scientific African, 2. https://doi.org/10.1016/j.sciaf.2018.e00014.

Evaluation of optimal rate of blended NPKSZnB fertilizer for hot-pepper (*Capsicum annum* L.) under Irrigation Condition at Merb-Lekhe Woreda, Central Tigray, Ethiopia

Tsadik Tadele[1]*, Geberesemaeti Kahsu[1], Weldegebrel Gebrehiwet[1], Tewolde Berhe[1], Kinfe Tekulu[1], Tarekegn Yibabie[1], Solomon Mebrahtom[1], Samrawit Mebrahtu[1], Gidena Tasew[2]

[1] Tigray Agricultural Research Institute, Shire Soil Research Centre, P.O. Box 40, Shire, Ethiopia

[2]Tigray Agricultural Research Institute, Mekelle Soil Research Center, P.O. Box 1070, Mekelle, Ethiopia

*Correspondence: tsadiktadele27@yahoo.com

Abstract

A field experiment was carried out in 2016 off-season at Medhin Kebele in Merb-Lekhe Woreda in Tigray Regional State, Ethiopia. The experiment was arranged in a randomized complete block design (RCBD) with three replications at two farmers' fields. Treatments used were seven levels of NPKSZnB (25, 50, 100, 150, 200, 250 and 300 kg ha^{-1}) and one standard check or blanket recommended NP fertilizer (96 kg N ha^{-1}and 69 kg P ha^{-1}). All the NPKSZnB treatments were evaluated to each other and against the blanket recommended NP fertilizer. Except the urea fertilizer which was applied as top dress 45 days after planting, all the blended fertilizer rates and DAP were spread over during hot pepper transplanting. Application of different rates of blended fertilizer did not significantly affect most of the crop parameters tested. The maximum plant height (64.87 cm) and pod diameter (0.91 cm) were obtained from plots treated with 250 and 150 kg NPKSZnB ha^{-1}, respectively. On the other hand, the result revealed that hot pepper yield increased with increased application of blended NPKSZnB fertilizer, though the difference was economically insignificant. Thus effect of the various rates and blanket recommended NP fertilizers were not statistically different as a result the least cost economically feasible rate was 25 kg ha-^{1} NPKSZnB ha^{-1}.

Keywords: Blended fertilizer, hot pepper, marginal rate of return, marketable yield

Introduction

Pepper encompasses about 30 species, but hot Pepper *Capsicum annuum* L. is the most cultivated species in both tropical and temperate zones (Grubben and El Tahir 2004). Hot pepper (*Capsicum annum* L.) belongs to the *Solanaceae* family. It is an important spice and vegetable crop in tropical areas of the world. It is the second most vital vegetable crop of the family after tomato in the world (Rubatzky and Yamaguchi 1997; Berhanu et al 2011). It is an important crop, not only because of its economic importance, but also due to the nutritional and medicinal value of its fruit (Nimona 2018). In Ethiopia, hot pepper is commonly cultivated within an altitude ranges of 1400 to 1900 meter above sea level [Ministry of Agriculture and Rural

Development (MoARD 2009); (Ethiopian Agricultural Research Institute (EIAR 2007)], which receives mean annual rainfall of 600 to 1200 mm, and has mean annual temperature of 25 to 28°C (EIAR 2007).

In terms of total production, the share of hot pepper in Ethiopia is high as compared with other vegetables such as lettuce, tomatoes, head cabbage, onion and others [Central Statistical Agency (CSA 2016)]. In Tigray Regional State, the total area under hot pepper for dry pod (*Berbere*) and for green pepper (*Karia*) in 2016 were estimated to be 1712.48 ha and 362.89 ha, respectively, while in Central Zone of Tigray the total area covered with hot pepper was 359.98 ha (CSA 2016). However, in the region the productivity is still low attributed to lack of proper nursery and field agronomic management practices (in adequate and/or unbalanced nutrient supply, diseases, poor aeration and lack of high yielding cultivars).

Nutrient deficiency is the major yield limiting factor on vegetable production in Ethiopia; N, P and other nutrients as S, B and Zn deficiencies are the foremost constraints for production of vegetables and other crops (Alemu and Ermias 2000). Fertilizers are efficient exogenous source of plant nutrients (Akram et al 2007). Plant growth and production necessitates sufficient and balanced nutrient supply as well as optimum uptake in order to maximize productivity (Mengel and Kirkby 2001). Application of mineral NPK fertilizers enhanced yield and yield contributors through better nutrient uptake, growth and development (Obidiebube et al 2012). Supply of micronutrients along with NPK fertilizer can also increase nutrient use efficiency of crops (Malakouti 2008).

Farmers, produce vegetable crops including hot pepper using blanket fertilizer recommendation in Ethiopia (EIAR 2007) such as (96 N + 64 P kg) ha^{-1} in Mereb-Lekhe Woreda. Increasing crop yields through application of N and P alone can deplete other nutrients Food and Agriculture Organization (FAO), 2000]. The depletion of important nutrient elements in soils such as K, magnesium (Mg), calcium (Ca), S and micronutrients might be aggravated due to unbalanced application of plant nutrients (Wassie et al 2011). As a result, the current productivity of hot pepper is very low compared to the potential yield of the crop, in all parts of the country (Nimona 2018). Continuous intensive cropping of hot pepper and other crops with inadequate fertilizer use has resulted in depletion of the soil's macro and micronutrients which in turn reduces yield (Gerstenmier 2015).

Fertilizer research works in Ethiopia have been focused on N and P under different soil types and various climatic conditions, while very limited work has been reported with other essential macro and micro nutrients (Nimona 2018). According to the soil inventory data acquired from EthioSIS, other than N and P, essential nutrients such as K, S, Zn, B and copper (Cu) are deficient in Ethiopian soils and their deficiency symptoms were observed on major crops in different parts of the country [Agricultural Transformation Agency (ATA), 2013[. However, no information is available on blended fertilizers requirement of hot pepper. Therefore, the presented study was aimed to validate the soil fertility map based blended fertilizer recommendation under specific production environment and to determine an economically optimum blended NPKSZnB fertilizer rates for better hot pepper production in Mereb-Lekhe Woreda.

Materials and Methods

Description of the study area

The experiment was conducted for two consecutive irrigation seasons (2016 and 2017) on farmers' fields at Hamedo scheme, Medhin Kebele of Mereb-Lekhe Woreda (Figure 1), following the map developed by EthioSIS for that specific area. The area mainly lies under semi-arid tropical belt of Ethiopia with a hot to warm agro-climatic zone with a mono-modal and erratic rainfall pattern. Hamedo irrigation scheme is found at around 50 km away to the north of Adwa town and 5 km away to the south of Rama town. The soil texture of the study area is characterized as sandy loam and loam [Office of Agriculture and Rural Development (OoARD 2019)].

The study area obtains a rainfall of 586.9 mm during the cropping season (January-December, 2016) (Figure 2). Mean maximum and minimum temperatures during the cropping season were 42.4^{o}C and 11.5^{o}C, respectively (Figures 2). The weather condition of the experimental site was suitable for hot pepper production according to the climatic data (OoARD 2019).

Experimental design and treatments

The experiment was set in RCBD with three replications. The plot sizes was 3 m by 3 m (9 m^2) and the spacing between blocks, plots, rows and plants were also 100, 50, 70, and 30 cm, respectively. Improved pepper variety (*Melka shote*) was used. This experiment was conducted in one season.

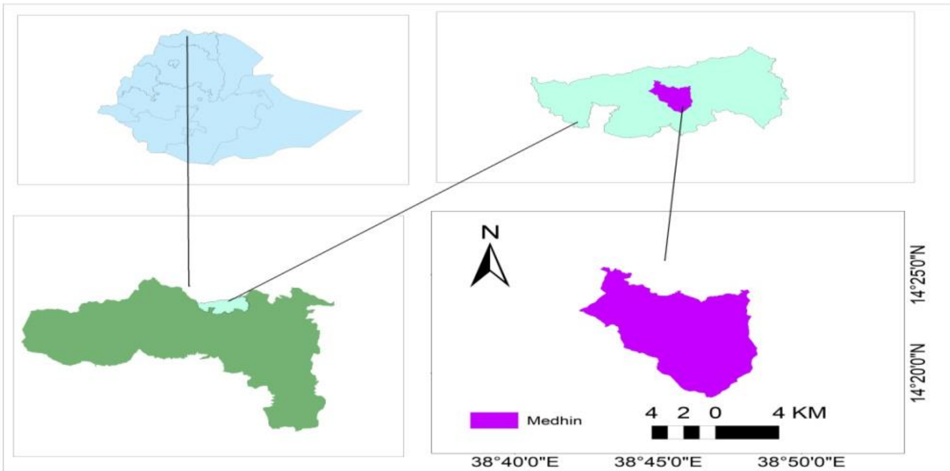

Figure 1. Location map of the study area at Mereb-Lekhe, Tigray, Ethiopia

A total of eight treatments; seven NPKSZnB rates (25, 50, 100, 150, 200, 250 and 300 kg ha^{-1}) and one blanket recommended fertilizer (105 kg N ha^{-1} and 69 kg P ha^{-1}) from DAP and urea were formulated and examined. All the NPKSZnB treatments were evaluated to each other and against the blanket recommended NP fertilizer. The same amount of urea fertilizer (64 kg N ha^{-1}) was applied to all plots that received different NPKSZnB fertilizer rates. Except the urea fertilizer which is applied as top dress 45 days after planting all the blended fertilizer rates and DAP were spread over during onion transplanting. The test crop was also planted in rows. The other hot pepper management practices were performed as per the recommendation.

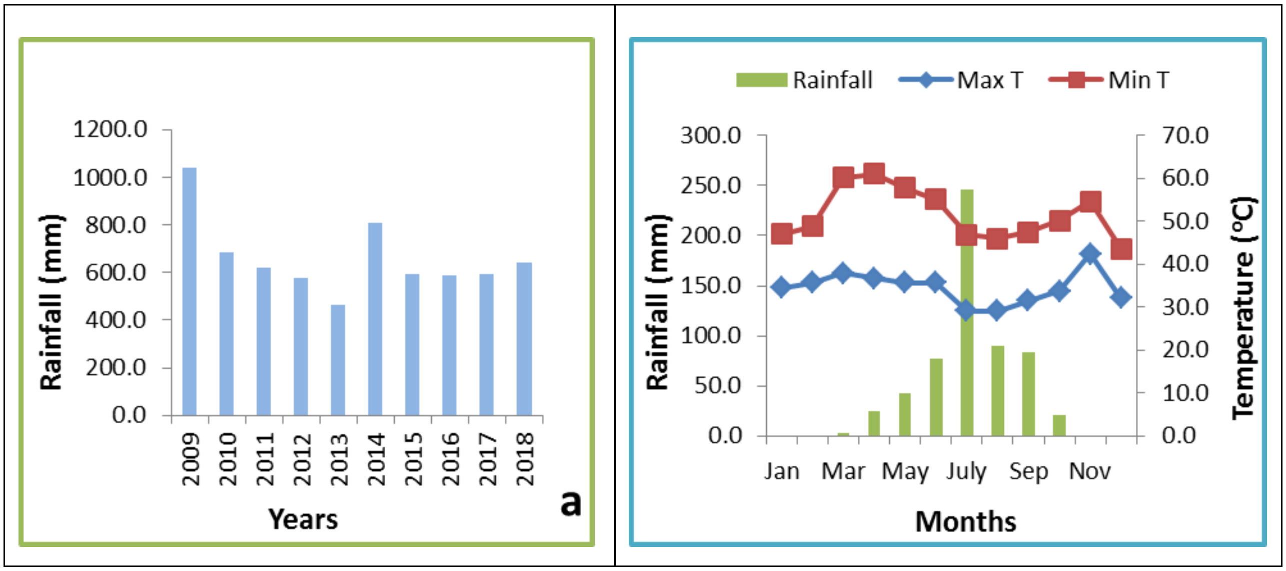

Figure 2. Ten years (2007-2016) annual rain fall (a) mean monthly rainfall, maximum and minimum temperature (b) in 2016 for Mereb Lekhe Woreda. Source: National Meteorological Services Agency, Tigray Branch office, 2019

Soil data collection and analysis

A representative composite soil sample was taken at 0 to 20 cm depth before planting, from each farmer's fields using an auger. The collected samples were properly labeled, packed and taken to Shire Soil Research Center. Particle size distribution was determined using the Bouyoucos hydrometer method (Bouyoucos, 1962). The pH and electrical conductivity (EC) (1:25 soil to water suspension) of the soil were measured using a pH meter (Rhoades, 1982) and the method described by Jakson (1967), respectively. Organic carbon (OC), total N and available P were also determined by the Walkely and Black (1934) method, Kjeldahl method as described by Bremner and Mulvaney (1982) and Olsen method (Olsen et al 1954), respectively. Results of the selected soil physicochemical properties of the experimental site are indicated in Table 1.

Table 1. Initial physicochemical properties of soil

Parameters	Values	Rating	Reference
pH	6.8	Neutral	Murphy (1968)
ECe (ds m^{-1})	1.71	Low soil salinity	Lamond and Whitney (1992)
OC (%)	0.72	Low	Tekalign (1991)
TN (%)	0.04	Low	Berhanu (1980)
Olsen-P (mg kg^{-1})	5.21	Medium	Olsen et al (1954)
CEC (cmol (+) kg^{-1})	10.12	Low	Landon (1991)
Ex. Ca (cmol (+) kg^{-1})	5.21	Medium	FAO (2006)
Ex. Mg (cmol (+) kg^{-1})	1.12	Medium	FAO (2006)
Ex. Na (cmol (+) kg^{-1})	0.18	Low	FAO (2006)
Ex. K (cmol (+) kg^{-1})	0.13	Low	FAO (2006)

Crop data collection

Agronomic data like planting date, flowering, and 50% pod setting, pod length, pod diameter, pod weight, plant height, days to maturity and yield were collected.

Data analysis

The collected data were subjected to statistical analysis. Analysis of variance (ANOVA) was carried out using Statistical Analysis System (SAS) software program (SAS 2002). Significant difference between and among treatment means were assessed using the least significant difference (LSD) at 0.05 level of probability (Gomez and Gomez 1984).

Economic analysis

Economic feasibility of the treatments was determined using economic analysis (partial budget, dominance, and marginal analyses). In partial budget analysis the yield has been adjusted 10% lower than the actual yield acquired from the experimental plots to make the representative yield at the farmers' fields. The average open market price (Birr kg^{-1}) and the official prices of the balanced fertilizers were also used for analysis. For a treatment to be considered a worthwhile option to farmers, the minimum acceptable rate of return (MARR) should be 100% [International Center for Maize and Wheat Research (CIMMYT 1988], which is suggested to be realistic. This enables to make farmer recommendations from marginal analysis. The expenses for fertilizer (NPKSZnB) and daily labor were calculated by assuming 1781.64 ETB per 100 kg fertilizer and 60 ETB per person, respectively. The revenue was also estimated by considering the prevailing market price of hot pepper which was 35 ETB per kg of yield.

Average marketable yield (MY) (kg ha^{-1}): is an average yield hot pepper on each treatment
Adjusted yield (AjY): is the average yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers' field.

$$AjY = MY - (MY * 0.1)$$

Gross field benefit (GFB) or Total revenue (TR**)**: was computed by multiplying field/farm gate price that farmers receive for the crop when they sale it as adjusted yield.

$$TR = AjY * \text{field or farm gate price of a crop}$$

Total variable cost (TC): is the cost of inputs that were used for the experiment as mean current prices of the blended NPSZnB and other fertilizers, wage for fertilizers application and transport of fertilizers, and were considered per hectare.

Net revenue (NR): was calculated by subtracting the total costs from the total revenue (gross field benefit) for each treatment.

$$NR = TR – TC$$

Marginal rate of return: percent marginal rate of return was calculated as changes in net benefit (raised benefit) divided by changes in cost (raised cost).

$$MRR (\%) = (MB/MC)*100$$

Where; Marginal cost (MC) = change in costs between treatments and Marginal benefit (MB) = change in net benefits between treatments.

Results and Discussion

Effects on days to first maturity, plant height, pod length and pod diameter

According to the result presented in Table 2, days to first maturity of hot pepper was different as affected by the NPKSZnB blended fertilizer rates. However, there was no statistically significant difference among the treatments including with the blanket recommended NP fertilizer. In contrary to this finding, application N and P had a significance difference among the treatment of hot pepper (Tibebu and Bizuayehu 2014). Similarly, increasing NPS fertilizer level increased days to maturity of potato cultivars and duration of vegetative phase of potato also prolonged and in turn maturity date delayed (Alemayehu and Jemberie 2018 and Manoj et al 2013).

Plant height of pepper was significantly affected by the different NPKSZnB blended fertilizer rates though it was in par with the blanket recommended NP fertilizer (Table 2). Inline to the current study, Nimona et al (2018) reported that application of different blended fertilizer rates significantly ($P \leq 0.05$) increased plant height of hot pepper. Although it is in parity with most of the treatments, longest plant height was recorded from plots that received 250 kg NPKSZnB ha^{-1}, whereas the shortest was from plots received 25 kg NPKSZnB ha^{-1}. Hence, the results indicated that application of blended fertilizers had enhanced vegetative growth of hot pepper. This increment in plant height might be due to the increasing cell division and elongation (Wahocho et al 2016) caused by the availability of nutrients in the blended fertilizers, especially N and P. In harmony to this finding, Bhuvaneswari et al (2014) also revealed that increment in plant height was obtained as the rate of blended fertilizer increased which might be attributed to N which contributes for plant elongation and for initiating growth promoting hormones (Indole-3-acetic acid or IAA).

Pod length was not significantly ($P \leq 0.05$) affected by the levels of blended NPKSZnB fertilizer (Table 2). Though, the longest pod length was recorded at 250 kg ha^{-1} NPKSZnB while the shortest pod was obtained from 25 kg ha^{-1}NPKSZnB. In contrary to this finding Sultana et al (2016) obtained that blended fertilizer significantly affected pod length of hot pepper. Hot pepper pod diameter was statistically significantly ($P \leq 0.05$) affected by the blended NPKSZnB fertilizer rates (Table 2). Highest pod diameter was obtained from plots planted with 150 kg NPKSZnB ha^{-1} fertilizer rate. Inline to this finding, Sultana et al (2016) and Wakuma (2017) obtained that blended fertilizer significantly affected pod diameter of hot pepper.

Table 2. Days to first maturity, plant height, pod length and pod diameter of hot pepper as influenced by blended NPKSZnB fertilizer rates under irrigation condition

Treatments	DMF (days)	PH (cm)	PL (cm)	PD (cm)
Rec. NP (119 kg N ha^{-1}, 69 kg P ha^{-1})	63.33	61.33ab	10.02	0.80abc
25 NPKSZnB (kg $ha-^{1}$)	62.00	58.20b	9.47	0.67c
50 NPKSZnB (kg $ha-^{1}$)	63.67	59.73ab	9.91	0.69bc
100 NPKSZnB (kg $ha-^{1}$)	60.00	63.53ab	10.27	0.84ab
150 NPKSZnB (kg $ha-^{1}$)	60.00	60.00ab	10.23	0.91a
200 NPKSZnB (kg $ha-^{1}$)	63.00	59.67ab	10.31	0.72bc
250 NPKSZnB (kg $ha-^{1}$)	62.67	64.87a	10.53	0.73bc
Mean	62.10	61.05	10.11	0.77
LSD ($_{0.05}$)	NS	5.72	1.56	0.16
CV (%)	3.56	5.27	8.49	11.95

Means followed by the same letters are not significantly different ($P \leq 0.05$) according to Tukey Test; DMF=Day to First Maturity, PH=Plant Height, PD= Pod Diameter, PL= Pod Length, ha= hectare; kg= Kilo Gram, NS= Non significant, CV= Coefficient of variation, LSD = Least significant differences.

Effects on yield component and yield

Hot pepper pod weight was not significantly ($P \leq 0.05$) affected by the different rates of blended NPKSZnB fertilizer (Table 3). Though, the highest green pod weight was recorded from plots that received 200 kg ha^{-1} blended NPKSZnB fertilizer rate, whereas the lowest was recorded from the 25 kg ha^{-1}. In contrary to this finding, application N and P had significance differences in pod weight among the treatment of hot pepper (Tibebuand Bizuayehu 2014).

Blended NPKSZnB fertilizer rates did not significantly ($P \leq 0.05$) influence number of pods (Table 3). Although all rates were statistically in par the highest pod number was obtained from the blended NPKSZnB fertilizer rate of 250 kg ha^{-1}, whereas the fewest was recorded from plots that received the 25 kg ha^{-1}. Contrary to this finding, application N and P had significance differences in pod number among the treatment applied to hot pepper (Tibebuand Bizuayehu 2014).

The PDST of hot pepper was not significantly ($P \leq 0.05$) affected by the different rates of blended NPKSZnB fertilizer (Table 3). Though, the highest pepper PDST was recorded in response to NPKSZnB fertilizer applied at the rates of 50 kg ha^{-1} the lowest was obtained from plots that received 250 kg ha^{-1} NPKSZn fertilizer rate. Similarly, pepper PDMT was not significantly ($P \leq 0.05$) affected by the different rates of blended NPKSZnB fertilizer under irrigation condition. Though, highest PDMT was obtained in response to the 250 kg ha^{-1} rate of the blended NPKSZnB fertilizer, whereas the lowest was recorded from plots that received 50 kg NPKSZnB ha^{-1} rate (Table 3). Marketable yield of hot pepper was not significantly influenced by the different blended NPKSZnB fertilizer rates (Table 3). However, plots that received 250 kg ha^{-1} NPKSZnB gave higher marketable yield than the other treatments.

Table 3 PDWT, PDN, PDST, and PDMT and marketable of pepper as influenced by blended NPKSZnB fertilizer rates under irrigation condition

Treatments	PDWT (g)	PDN (unit)	PDST (days)	PDMT (days)	MY (kg ha^{-1})
Rec. NP (119 kg N ha^{-1}, 69 kg P ha^{-1})	0.30	64.53	82.67	96.33	8246
25 NPKSZnB (kg ha-^{1})	0.25	53.47	82.67	96.33	7237
50 NPKSZnB (kg ha-^{1})	0.28	56.13	81.33	95.00	7719
100 NPKSZnB (kg ha-^{1})	0.31	57.87	82.33	96.33	8246
150 NPKSZnB (kg ha-^{1})	0.31	58.33	81.67	95.33	8333
200 NPKSZnB (kg ha-^{1})	0.38	59.13	82.33	96.67	8333
250 NPKSZnB (kg ha-^{1})	0.27	64.8	83.33	97.00	8597
Mean	0.30	59.18	82.38	96.14	8102
LSD ($_{0.05}$)	NS	NS	NS	NS	NS
CV (%)	25.23	11.65	1.24	1.38	12.81

Means followed by the same letters are not significantly different ($P \leq 0.05$) according to Tukey Test; PDWT=Pod weight, PDN=Pod Number, PDST=Pod setting, PDMT=Pod maturity, MY=Marketable Yield, ha= hectare; Kg= Kilo Gram, NS= Non significant, CV= Coefficient of variation, LSD = Least significant differences.

Pepper yield increased with an increasing NPKSZnB fertilizer rates at the study area. Therefore, the optimum blended NPKSZnB fertilizer rate might be beyond 250 kg ha^{-1} because the response curve is still showing an increasing trend. Inline to the current study Matta and Cotter (1994) reported that hot pepper yield increased in response to addition of nutrients in nutrient deficient soils which may increase vegetative growth, leaf area, photosynthetic capacity and may cause better partitioning of assimilate towards the pods.

Partial budget analysis

According to this study, hot pepper yield increased with increased application of blended NPKSZnB fertilizer, though the difference was economically insignificant. Cost-benefit analysis was undertaken for the different fertilizer rates to determine the highest net benefit. The maximum pepper yield was obtained from plots that received highest rate of blended NPKSZnB fertilizer. However, since the effect of the various rates and blanket recommended NP fertilizer were not statistically different, the 25 kg ha^{-1} rate which is in this case the least cost economically feasible is recommended.

Table 3. Partial budget analysis of blended NPKSZnB fertilizer for pepper at Mereb-Lekhe Woreda

Fertilizer rate (kg K/ha)	FC (Birr)	TLC [Birr]	TVC [Birr]	MY (kg/ha)	AjY (kg/ha)	TR [Birr]	NR [Birr]	MRR (ratio)	MRR (%)
25 NPKSZnB (kg ha-^{1})	445.41	30	475.41	7237	6513	117239	116764	0.00	0.00
50 NPKSZnB (kg ha-^{1})	890.82	60	950.82	7719	6947	125048	124097	15.42	1542.46
100 NPKSZnB (kg ha-^{1})	1781.64	120	1901.64	8246	7421	133585	131684	7.98	797.90
150 NPKSZnB (kg ha-^{1})	2672.46	150	2822.46	8333	7500	134995	132142	0.48	48.23
200 NPKSZnB (kg ha-^{1})	3563.28	210	3773.28	8333	7500	134995	131191	D	D
250 NPKSZnB (kg ha-^{1})	4454.1	270	4724.1	8597	7737	139271	134517	1.25	124.90
Rec. NP (105 N, 69 P kg ha^{-1})	4660.5	330	4990.50	8246	7421	133585	128595	D	D

Where; FC= Fertilizer cost, TLC= transport and labor cost, TVC= Total variable cost, MY= marketable yield, AjY= Adjusted yield, TR= Total Revenue, NR= Net revenue and MRR= marginal rate of return.

Conclusion

Fertilizer application for vegetable crops under irrigation condition has been practiced since long time ago in Mereb-Lekhe Woreda. However, the yield and economic return have been reduced from time to time due to the use of a few fertilizer recommendations in all conditions for different crops. Furthermore, the blanket recommendations had caused unbalanced nutrient constituents which made it inefficient in agronomical point of view. Therefore, this study was initiated to improve sustainable hot-pepper production and productivity through development of crop and soil specific blended fertilizers.

Marketable yield showed increasing trend with increasing the blended fertilizer rates. Additionally, the highest marketable yield (8597 kg ha^{-1}) was recorded from the blended fertilizer rate of 250 kg ha^{-1} NPKSZnB + 64 kg N ha^{-1} urea top dress and the lowest (7237 kg ha^{-1}) from plots that received (25 kg ha^{-1}NPKSZnB + 64 kg N ha^{-1} urea top dress. However, the yields of these rates were not statistically different to each other and with that of the previously recommended N and P fertilizers for hot pepper production in Ethiopia. Hence, the lowest NPKSZnB rate (25 kg ha^{-1}NPKSZnB + 64 kg N ha^{-1} urea top dress) will be economically feasible.

Reference

Akram A Fatima M Ali S Jilani G Asghar R (2007): Growth, yield and nutrients uptake of sorghum in response to integrated phosphorus and potassium management. *Pak. J. Bot.* 39(4): 1083-1087.

Alemayehu M and Jemberie M (2018): Optimum rates of NPS fertilizer application for economically profitable production of potato Cultivars at Koga Irrigation Scheme, Northwestern Ethiopia. *Cogent Food & Agriculture* 4(1): 1-17.

Alemu Haiylie and Ermias Abate (2000): Horticultural crops production and associated constraints in North-west Ethiopia. Working paper. Agricultural Economics Research Division, Agricultural Research Centre, Adet. 18p.

ATA (Agricultural Transformation Agency) (2013): Status of soil resources in Ethiopia and priorities for sustainable management. Ethiopian agricultural transformation agency In: Global Soil partnership (GSP) for eastern and southern Africa. March 25-27: 2013, Nairobi, Kenya.

Berhanu Debele (1980): The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land Use Planning and Regulatory Department, Ministry of Agriculture, Addis Ababa, Ethiopia.

Berhanu Yadeta Derbew Belew Wosene Gebresillase and FekaduMarame (2011): Variability, heritability and genetic advance in hot pepper (Capsicum annuum L.) genotypes in west

Shoa, Ethiopia. *American-Eurasian Journal of Agriculture and Environmental Science* 10(4), 587 –592.

Bhuvaneswari G Sivaranjani R Reetha S and Ramakrishan K (2014): Application of nitrogen fertilizer on plant density, growth, yield and fruit of bell peppers (*Capsicum annuum* L.). *International Letters of Natural Sciences*, 8(2): 82 – 92.

Bouyoucos J (1962): Hydrometer method improved for making particle size analysis of soil. *Agronomy Journals* (54):464-465.

Bremner JM and Mulvaney CS (1982): Nitrogen - Total. *In* Page AL Miller RH and Keeney DR (eds.). Methods of soil analysis. Part 2-Chemical and microbiological properties. *American Society of Agronomy* 9 (2): 595-624.

CIMMYT (International Center for Maize and Wheat Research) (1988): From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico.

CSA (Central Statistical Agency) (2016): Agricultural Sample Survey. Report on area and productivity of crops. Statistical Bulletin, Volume I. Addis Ababa.361p.

EIAR (Ethiopia Institute of Agricultural Research) (2007): Technology guideline for different crops. Amharic Version Addis Ababa, Ethiopia. pp. 121-124.

FAO (Food and Agriculture Organization) (2000): Guidelines for On-Farm Plant Nutrition and Soil Management Trials and Demonstrations, AGL/MISC26/2000.

Gerstenmier A (2015): Agricultural Input Supply. Abdou Diouf International Conference Center, Dakar Senegal, 21-23 October 2015.

Gomez and H Gomez (1984): Statistical analysis for agricultural research. John Willy and Sons Inc. pp.120-155.

Grubben GJH El Tahir IM (2004): Capsicum annuum L. *In*: Grubben GJH and Denton OA (eds.). PROTA 2: Vegetables/Légumes. [CD- Rom]. PROTA, Wageningen, the Netherlands.

Jackson ML (1967): Soil chemical analysis. Practice Hall of India. New Delhi.

Lamond R and Whitney DA (1992): Management of saline and sodic soils. Kansas State University, Department of Agronomy MF-1022.

Landon JR (1991): Booker Tropical Soil Manual: A hand book for soil survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical, Essex, New York. 474p. OR John Wiley & Sons Inc., New York.

Malakouti MJ (2008): The effect of micronutrients in ensuring efficient use of macronutrients: Soil Science Department; Tarbiat Modares University. *Turk J. Agric* (32) 215-220.

Manoj K Meena ML Sanjay K Sutanu M and Devendra K (2013): Effect of nitrogen, phosphorus and potassium fertilizers on the growth, yield and quality of tomato var. Azad T-6. .*Asian Journal of Horticulture* 8(2): 616-619.

Matta FB and Cotter DJ (1994): Chile Production in North- Central New Mexico. Cooperative Extension Circular Guide. Las Cruces. H-225.

Mengel K and Kirkby EA (2001): Principles of Plant Nutrition, 5thed. Kluwer Academic publishers: dordrecht, the Netherlands, pp. 481–509.

MoARD (Ministry of Agriculture and Rural Development) (2006): Variety Register. Issue 9, 2006. Addis Ababa, Ethiopia.

Murphy HF (1968): Reports on fertility status of some soils and other data on soils of Ethiopia College of Agriculture HSIU, Addis Ababa, Ethiopia; Experiment Station Bulletin No.44. 551p.

Nimona Fufa Hunde (2018): Effects of Blended Fertilizer Rates on Yield, Yield Components and Nutrient Use Efficiencies of Hot Pepper (Capsicum annuum L.) at Asossa, Western Ethiopia. Thesis. Hawasa University, Collage of Agriculture.

Obidiebube EA Eruotor PG Akparobi SO Emosaariue SO Achebe UA and Kator PE (2012): Response of four cultivars of pepper (Capsicum frutescens L.) to different levels of N, P and K fertilizer in rainforest Agro-ecological zone. *Int. J. Agric. Sci.* 2(12):1143-1150.

Olsen R. Cole S Watanabe, F and Dean L (1954): .Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *United States Department of Agriculture* Circ. 939.

OoARD (Bureau of Agriculture and Rural Development) (2019): Annual report of Bureau of the Agricultural and Rural Development of Merb lekhe Woreda.

Rhoades JD (1982): In Methods of Soil Analysis, Part 2.Second Edition (A.L. Page.Miller and D.R. Keeney, Eds.), *American Society of Agronomy*. Madison, USA.

Rubatzky V and Yamguchi M (1997). World Vegetables, 2nd Edition. International Thomson Publishing, USA. 562pp.

SAS (Statistical Analysis software) (2002): SAS/STAT User's Guide, Version 9.1.3. SAS institute Inc., Cary, NC.

Sultana S Naser HM Akhter S and Begum RA (2016): Effectiveness of soil and foliar applications of zinc and boron on the yield of Tomato. *Bangladesh Journal of Agricultural Research* 41(3): 411-418.

Tekalign Tadese (1991) Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13.International Livestock Research Center for Africa, Addis Ababa, Ethiopia .and Subtropics. Longman Scientific and Technical, Essex, New York. 474p.

Tibebu Simon and Bizuayehu Tesfaye (2014): Growth and Productivity of Hot Pepper (*Capsicum annuum* L.)as Affected by Variety, Nitrogen and Phosphorous at Jinka, Southern Ethiopia.*Journal of Biology, Agriculture and Healthcare* 4 (17): 2224-3208

Wahocho NA Zeshan Ahmed S Jogi Q Talpur KH and Leghari SJ (2016): Growth and Productivity of Chilli (*Capsicum Annuum* L.)Under Various Nitrogen Levels. *Science International* 28(2): 1321-1326.

Wakuma Biratu (2017): Growth and yield response of hot pepper (*capsicum annuum* l.) to blended fertilizer rates and cultivars in Raya Azebo, Northern Ethiopia. M.Sc. Thesis, Jimma University, Ethiopia.

Walkley A and Black IA (1934). An examination of the method for determining soil organicmatter and proposed chromic acid titration method. *Soil Science*, (37):29-38.

Wassie Haile and Shiferaw Boke (2011). Response of Irish Potato (Solanum tuberosum) to the Application of Potassium at Acidic Soils of Chencha, Southern Ethiopia. International *Journal of Agriculture and Biology* 13:595-598.

Evaluation of NPSZnB Fertilizer on Yield Component and Yield of Sesame *(Sesame Indicum L.)* Under Rain-Fed Condition in Western Zone of Tigray, Ethiopia

Team Shimgabr*, Negasi Gebreslasie, Haile Alene, Nebyu Tsegay and Welesenbet Haftu

Tigray Agricultural Research Institute, Humera Agricultural Research Center, P.O.Box 62, Humera, Ethiopia

*Correspondence: teame15sh@gmail.com

Abstract

Sesame is one of the most popular oil crops in Western Zone of Tigray, Ethiopia. Blended fertilizers containing nitrogen (N), phosphorus (P), sulfur (S), Zinc (Zn) and boron (B) have been recommended to ameliorate site specific nutrient deficiencies in different WoredaWoredas of Tigray. Field experiment was conducted in Kafta Humera on Vertisols during rainfall season of 2018 to study the effect of NPSZnB fertilizer on sesame *(Sesame indicum L.)* nutrition. The experiment was laid out in randomized completely block design (RCBD) with three replication. The experiment consisted of seven treatments of which six levels were NPSZnB (0, 50, 100, 150, 200 and 250 kg ha^{-1}) and one blanket recommendation of NP. Data were recorded on sesame yield and yield components. The results revealed that addition of graded rate of NPSZnB significantly increased yield and yield attributes of sesame. Grain yield increased from 373.36 kg ha^{-1} to 508.78 kg ha^{-1} as NPSZnB increases from 0 to 200 kg ha^{-1} NPSZnB but it was not significantly different from the blanket recommendation of N and P (41 kg N and 46 kg P_20_5 ha^{-1}).

Keywords: NPSZnB, yield, sesame

Introduction

Soil fertility depletion is the major constraint to sustainable agricultural production in Tigray. Poor soil fertility and extreme exhaustion of plant nutrients from the soil are the major factors limiting crop production in both rain-fed and irrigated farms in the different agro-ecological zones of Tigray. Nutrient mining due to sub-optimal fertilizer use coupled with agronomical unblended fertilizer uses have favored the emergence of multi-nutrient deficiency in Ethiopian soils (Asgelil et al 2007; Abyie et al 2003). This in part explains fertilizer factor productivity decline and stagnant crop productivity conditions encountered despite continued use of the blanket recommendation.

Among the key strategies that were identified to help increase agricultural production and productivity in Growth and Transformation Plan I (GTP I) period was the soil fertility mapping of the country's agricultural lands. The soil fertility map of Tigray region was completed in the year 2014 and published by Ministry of Agriculture (MOA) and Ethiopian Agricultural Transformation Agency (ATA) (2014) as part of the strategy. The necessity to transform agricultural sector with respect to soil fertility requires application of proper amounts of blended fertilizers for different crops. Blended fertilizers containing N, P, S, B, iron (Fe) and Zn in blend form have been recommended to solve site specific nutrient deficiencies and thereby increase crop production and productivity. The major recently recommended blended fertilizers for Tigray Region by MOA and ATA are NPS, NPSB, NPSZn, NPSZnB, NPSFeZn and NPSFeZnB. Though potassium (K) was part of the previous blend fertilizer, recently it was suggested to be applied based on soil test result. Because K is major nutrient and the amount of K in the previous blend fertilizers might not be sufficient for crop requirement.

Experimentations of blend fertilizers were carried out for the last few years in Tigray. However in most of the study sites, there were no significance difference among the different blend fertilizers as compared with the conventional N and P recommendation. The probable reasons could be blends were compared to each other and the formulation were containing insufficient amount of K. Although the type of required blended fertilizers are identified for the region, optimum rates of the major recommended blended fertilizer types for different crops, agro ecologies and soil types is not yet determined. Besides, verifying the soil fertility map for major crops grown in the region in different agro ecologies and on different soil types is urgently needed to increase crop yields and to improve quality of major crops. Therefore, it was imperative to investigate the effects of blended fertilizers recommended for Western Zone of Tigray in the fertilizer recommendation atlas for major crops grown under different agro ecologies on major soil types. Hence, experiment was conducted to evaluate NPSZnB fertilizer on yield and yield component of sesame.

Materials and Methods

Field experiment was conducted in the Western Zone of Tigray, Kafta Humera distrcit ($13^0$10' 0" to 14^0 29' 0" N latitude and 36^0 31' 0" to $37^0$34' 30" E longitudes at an average altitude of 609 m.a.s.l.) at Humera Agricultural Research Center site and Banat Tabia. The study was conducted to evaluate the effect of NPSZnB on sesame *(Sesamum indicum L.).* The experiment consisted of seven treatments of which six levels were NPSZnB (0, 50, 100, 150, 200 and 250 kg ha^{-1}) and one blanket recommendation of NP (41 kg N ha^{-1}, 46 kg P_2O_5 ha^{-1}). The experiment was conducted in RCBD. The N in the blended treatments was adjusted to the recommended N level. The amount of N was applied in split (one third at sowing and the remaining three weeks after sowing. The field was prepared well before sowing by plough twice with tractor and well leveled for seed bed. Seeds of sesame were planted in rows of plot size 4 m by 2.8 m long with spacing of 0.4 m between rows. Plots and blocks were separated by 1 m and 1.5 m unplanted distances, respectively. All agronomic operations under study were kept normal and uniform for all treatments.The plants were harvested at maturity and traits such as number of branch, plant height, number of capsules per plant and number of seeds per capsule were recorded on 5 randomly selected plants in each plot. Grain yield and biological yield were obtained by harvesting an area of 4 m^2 from the middle of each plot, to avoid marginal effects. Data collected was subjected to analysis of variance (ANOVA). Duncan's Multiple Range Test (DMRT) was used for mean separation where differences were significant, at 5% level of probability.

Results and Discussion

Growth attributes of sesame

Data presented in Tables 1 showed that application of different blended fertilizers had significant influenced ($P < 0.0001$) number of tiilers per plant, plant height, number of capsules per plant and number of seeds per capsule of sesame with increasing blended fertilizer application rates. The maximum number of tiilers per plant (3.62), plant height (137.69 cm) and number of seeds per capsule (69.16) were obtained from application of 200 NPSZnB kg ha^{-1} blended fertilizers. Several authors [Dewal and Pareek (2004), Arif et al (2006), Gupta et al (2004), Bereket et al (2014)] reported that macro and micro nutrients (N, P,S and B) fertilizers application can increase plant height, spike length, number of tillers and number of kernel of wheat with increasing doses and combination.

Yield of sesame

The maximum grain yield (508.78 kg ha^{-1}) was obtained from 200 NPSZnB kg ha^{-1} of blended fertilizer application. Conversely, the lowest grains yield (373.36 kg ha^{-1}) was observed in control plot. The grain yield increase from application of NPSZnB kg ha^{-1} was 36% more than the control. However, the recorded increase was not significantly different as compared to the previously recommended NP fertilizer.

Table 1. Response of yield and yield components of sesame to NPSZnB rates

NPSZnB fertilizer rates (kg ha^{-1})	NB	Ph (cm)	LPBZ (cm)	NCPP	NSPC	TSW (gm)	Yield (kg ha^{-1})
Control	2.58	127.24	56.69	40.20	63.84	2.66	373.36
Rec. NP (41 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1})	2.76	132.78	63.64	48.80	69.82	2.68	504.90
50	2.76	133.44	62.71	43.80	64.84	2.64	449.11
100	2.98	135.04	62.78	49.38	65.40	2.59	475.35
150	3.22	142.58	63.02	53.53	66.69	2.64	477.94
200	3.62	137.69	60.07	46.93	69.16	2.64	508.78
250	3.00	137.22	58.98	43.80	69.42	2.66	502.67
CV (%)	20.25	7.45	12.82	25.26	7.54	5.26	22.86
LSD	0.57	6.6	NS	11.22	4.81	NS	102.46
P-values (Treatment)	0.01	0.08	0.44	0.29	0.07	0.9	0.12
P-values (Site)	0.0001	0.0001	0.0001	0.1	0.0001	0.0001	0.0001
P-values (Tretment*Site)	0.02	0.2	0.15	0.09	0.063	0.78	0.51

NB=number of branch, Ph= plant height, LPBZ=length of pod bearing zone, NCPP= number of capsules per plant, NSPC= number of seeds per capsule and TSW= thousand seed weight

This result agrees with the previous finding of Woubshet et al (2017) who reported that application of 150 kg ha^{-1} NPSB blended fertilizer with compost increased grain yield of barley by 4.8 t ha^{-1}. Klikocka et al (2016) also reported positive interaction of N and S fertilization on grain yield of spring wheat.

Conclusion and Recommendation

One year result indicated that grain yield of sesame increased with an increase in rate of blended NPSZnB fertilizer. Maximum grain yield (508.78 kg ha^{-1}) was obtained from 200 NPSZnB kg ha^{-1} of blended fertilizer application. Conversely, the lowest grains yield (373.36 kg ha^{-1}) was obtained in control plot. However, the difference in yield was not significantly different as compared to the previously recommended NP fertilizer. Hence the experiment should be repeated in one more year to bring conclusive recommendation by incorporating the economic analysis.

References

Abiye Astatke, Tekalign Mamo, Peden D and Diedhiou M (2003): Participatory on-farm conservation tillage trial in Ethiopian highland Vertisols: The impact of potassium application on crop yield. *Experimental Agriculture* 40: 369 -379.

Arif M Ali S Khan A Jan T and Akbar M (2006): Influence of farmyard manure application on various wheat cultivars. *Sarhad Journal of Agriculture* 22 (1): 27- 29.

Asgelil D Taye B and Yesuf A (2007): The status of Micro-nutrients in Nitisols, Vertisolss, Cambisols and Fluvisols in major Maize, Wheat, Tef and Citrus growing areas of Ethiopia. In proceedings of Agricultural Research Fund. pp 77-96.

Bereket H Dawit H Mehretab H and Gebremedhin G (2014): Effects of Mineral Nitrogen and Phosphorus Fertilizers on Yield and Nutrient Utilization of Bread Wheat on the Sandy Soils of Hawzen Woreda, Northern Ethiopia. *Agriculture, Forestry, and Fisheries* 3(3): 189-198.

Dewal GS and Pareek RG (2004): Effect of phosphorus, Sulphur, and zinc on growth, yield and nutrient uptake of wheat (Triticum aestivum L.). *Indian J. Agronomy* 49: 160-162.

EthioSIS (Ethiopian Soil Information System) (2014): Atlas for Tigray regional state. Soil fertility status and fertilizer recommendation, EthioSIS, report.

Klikocka H Cybulska M Barczak B Narolski B Szostak B Kobiałka A Nowak A and Wojcik E (2016): The effect of Sulphur and nitrogen fertilization on grain yield and technological quality of spring wheat. *Plant Soil and Environ*. 62(5): 233-236.

Woubshet D Selamyihun K and Cherukuri V (2017): Effect of integrated use of lime, blended fertilizer, and compost on productivity, nutrient removal and economics of barley (*Hordeum vulgare L.*) on acid soils of high lands in West Showa Zone of Ethiopia. *Int. J. of Life Sciences* 5 (3): 311-322.

Evaluation of NPS Fertilizer on Yield and Yield Components of Sesame under Rain-fed Condition in Western Zone of Tigray, Ethiopia

Teame Shimgabr*, Negasi Gebereslasie, Haile Alene, NebyuTsegay and Welesenbet Haftu

[1]Tigray Agricultural Research Institute, Humera Agricultural Research Center

*Corrospondence: teame15sh@gmail.com

Abstract

Field experiment was conducted to determine optimum rate of the newly introduced NPS fertilizer on yield and yield components of sesame on Vertisols of Western Zone of Tigray, Ethiopia in 2018 at the Research Farm, Banat and Kebabo Kafta Humera and Tsegede Wereda's. The treatments consisted of six levels of NPS (0, 50, 100, 150, 200 and 250 kg ha^{-1}) and one blanket N and P recommendation. The experiment was laid out in a randomized block design (RCBD) with three replications. Application of different levels NPS fertilizer had significant effect ($p < 0.05$) on yield and yield components of sesame in the study areas. Analysis of variances showed that grain yield, plant height and thousand seed weight were significant at ($P< 0.05$). Grain yield increased from 338.78 kg ha^{-1} to 522.42 kg ha^{-1} as NPS increases from 0 (control) to 150 kg ha^{-1} NPS but it was not significant with blanket recommendation of N and P (41 kg N and 46 kg P_20_5 ha^{-1}).

Keywords: NPS, yield, Sesame, yield components

Introduction

Sources of plant nutrients for Ethiopian agriculture over the past five decades have been limited to urea, and di-ammonium phosphate (DAP) fertilizers which contains only nitrogen (N) and phosphorus (P), respectively that may not satisfy the nutrient requirements of crops including sesame. In this regard, however, Shiferaw (2014) reported that Ethiopian soils lack most of the macro and micronutrients that are required to sustain optimal growth and development of crops. This is exacerbated especially by Ethiopian fertilizer rates that are below international and regional standards (Agriculture Growth Program, 2013). Consequently, the yield and productivity of crops becomes low.

To avert the situation, the ministry of agriculture of Ethiopia has recently introduced a new compound fertilizer NPS containing N, P and sulfur (S) with the ratio of 19% N, 38% P_2O_5 and 7% S. This fertilizer has been currently substituted DAP in Ethiopian crop production system as main source of phosphorous (Ministry of Agriculture and Natural Resource, 2013). The situation is even more challenging for the researchers and smallholder farmers to understand the effects and identify the optimum rates of the newly introduced NPS fertilizer that contains S for economical production of crops including sesame. Most of the sesame producing farmers in the Western Zone of Tigray were advised to use the Blanket recommendation or national recommendation of P (64 kg P_2O_5 ha^{-1}) and N (41 N ha^{-1}), i.e. 50 kg of urea and 100 kg of DAP per hector, but the newly introduced NPS fertilizer also currently applied with the same trend of the blanket rate.

Eventhough there is fertilizer type recommendation for sesame, there is recommended optimum rate of NPS fertilizer for sesame under rain fed condition the study area. Even though, new blended fertilizer NPS are currently being used by farmer in the study area, some of the farmers informed that the blanket recommended fertilizer responded better than the NPS. Moreover, these agronomic practices vary depending on the physical and chemical properties of the soil, the soil moisture status; varieties grown etc. Thus, there is a need to develop area specific recommendation of blended NPS fertilizer rate in order to achieve maximum and higher yield of sesame ha^{-1}. Therefore, this study was initiated to assess the effect of blended NPS fertilizer rate on yield and yield components of sesame in the Kafta humera and Tsegedie Woredas of Western Zone of Tigray Ethiopia.

Materials and Methods

Experimental setup, treatments and procedures

Field experiment was conducted in the Western Zone of Tigray, Kafta Humera ($13^0$10' 0" to 14^0 29' 0" North latitude and 36^0 31' 0" to 37^0 34' 30" East longitudes at an average altitude of 609 masl) and Tsegede ($36^0$510'29'' - $37^0$05'25''E and $13^0$4'25''- $14^0$6'55''N with an elevation range of 700- 3000 masl.) Woreda. The experiments had six rates of NPS (19N, 38 P_2O_5, 7S) (0, 50, 100, 150, 200 and 250 kg ha^{-1}) treatments adjusted with N to the recommended level. It had also blanket recommended of N and P fertilizers (41 kg N ha^{-1}, 46 kg P_2O_5 ha^{-1}) as seventh treatment. The amount of N was applied in split application of 1/3 at sowing and the remaining was applied applied 3 weeks after sowing. The experiment was laid out in RCBD with three replications.

The field was prepared before sowing by ploughing twice with tractor and well leveled for seed bed. Seeds of sesame were planted in plot sizes of 4 by 2.8 m with spacing of 0.4 m between rows. Plots were separated by 1m and blocks by 1.5 m.

Data collection

All agronomic operations were kept normal and uniform for all treatments. The plants were harvested at maturity and traits such as number of branch, plant height, number of capsules per plant and number of seeds per capsule were recorded on 5 randomly selected plants in each plot. Grain yield and biological yield were obtained by harvesting from an area of 4 m by 2.8 m from the middle of each plot, to avoid marginal effects.

Data analysis

The collected data collected were subjected to analysis of variance (ANOVA). Duncan's Multiple Range Test (DMRT) was used for mean separation where differences were significant, at 5% level of probability (Gomez and Gomez 1884).

Results and Discussion

Growth attributes of sesame

The analysis of variance illustrated that the effect of NPS had significantly ($P < 0.0001$) influenced plant height. Similarly, the length of pod bearing zone and thousand seed weight were significantly affected ($P \leq 0.0001$) at the different sites. While the NPS*site interaction had no significant effect on those parameters. On the other hand, number of branch, number of capsule per plant and number of seeds per capsule had no significant effect. Moreover, the NPS*site interaction had no significant effect on the number of tillers, number of capsule per plant and number of seeds per capsule. In addition to this, the analysis of variance illustrated that the NPS with blanket recommendation of N and P had no significant difference in all the parameters and sites.

Grain yield

The mean grain yield of the three locations is presented in Table 1. The effects of NPS significantly ($P < 0.0001$) influenced grain yield at all the sites. However, the NPS*Site interaction had no significant effect on that parameter. Furthermore, the NPS with blanket recommendation of N and P had no significant effect on grain yield. At all locations, increasing the rate of NPS significantly increased grain yield over control. Thus, the highest grain yield was obtained at the rate of 150 kg NPS ha^{-1} at the three locations whereas the minimum were recorded for the control treatment. Thus, sesame plants grown at the rate of 150 kg NPS ha^{-1} produced about twice as much yield (additional increment of 35%) as compared to the grain yield produced in the plots treated with no fertilizer.

The results were generally similar to the findings of different researchers who reported positive response of NPS fertilizer rates at different areas on potato (Abewa and Agumas 2012; Boke 2014; Jemberie 2017; Mekashaw 2016). Positive influence of NPS fertilizer and other S-containing fertilizers have been also recorded on various vegetable crops (Gebremeskel 2016 and Hariyappa 2003).

Table 1. Response of yield and yield components of sesame to NPS rates

NPS fertilizer rates (kg ha^{-1})	NB	PH (cm)	LPBZ (cm)	NCPP	NSPC	TSW (gm)	GY (kg ha^{-1})
control (0)	3.11	118.56	57.82	40.38	64.42	2.48	338.78
41 N and 46 p_20_5	2.93	138.71	63.67	47.04	64.78	2.58	505.56
50 NPS	3.09	134.78	65.89	47.60	61.00	2.60	445.42
100 NPS	3.22	133.91	66.47	46.44	63.58	2.62	491.43
150 NPS	3.04	137.47	61.49	45.91	62.96	2.62	522.42
200 NPS	3.04	135.09	59.73	43.20	65.82	2.61	421.76
250 NPS	3.07	131.60	57.42	41.67	66.38	2.64	441.85
CV	26.64	25.42	11.21	29.18	9.28	6.12	25.42
LSD	NS	11.16	6.59	NS	NS	0.15	109.58
P-values (Trt)	0.99	0.017	0.03	0.85	0.54	0.38	0.03
P-values (Site)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
P-values (Trt*Site)	0.105	0.69	0.83	0.35	0.015	0.26	0.28

NB=number of branch, PH= plant height, LPBZ=length of pod bearing zone, NCPP= number of capsules per plant, NSPC= number seeds per capsule, TSW= thousand seed weight, GY= grain yield

Conclusion

In the present study, most growth parametrs and yield of sesame increased with increased application rates of NPS fertilizer. The highest sesame yield was recorded from plots treated with 150 kg NPS ha^{-1} fertilizer. However, this result was statistically similar with the yield obtained from the blanket recommendation that was N and P fertilizer at the rate of 41N and 46 P_2O_5 kg ha^{-1}. Based on the result, 150 NPS kg ha^{-1} fertilizer rate gave highest production of sesame, on Vertisols of the experimental fields. Nevertheless, since this result is one year data, the experiment should be repeated.

Reference

Abewa A and Agumas B (2012): Response of irrigated potato (Solanum tuberosum L.) to nitrogen fertilizer at Koga Irrigation Scheme, West Gojjam. In Gizaw, D. (ed.), Proceedings of the First Workshop on Agricultural Water Management Research and Development in Amhara Region. Bahir Dar, Ethiopia.

Agriculture Growth Program (2013): From sample blended fertilizers to ample yields. Retrieved from http://ethioagp. org/from-sample-blended-fertilizers-to-ample-yields/

Boke S (2014): Effects of organic and inorganic fertilizer application on potato yield and soil properties on Alisols of Chencha. Africa Journal of Science, 2(8), 123–132

Gebremeskel DK (2016): Assessment of production practices and effect of N:P2O5:S rates on yield and yield components of head cabbage (Brassica oleracea var. capitata) under irrigation conditions in Lay Armachio Woreda, Amhara Region, Ethiopia. (MSc thesis). Bahir Dar University, Ethiopia.

Gomez KA and Gomez AA (1984): *Statistical procedures for agricultural research, 2nd edition*. John Viley and Sons Inc., New York

Hariyappa N (2003): Effect of potassium and sulfur on growth, yield and quality parameters of onion (Allium cepa L) (MSc thesis). University of Agricultural Sciences, Dharwad, India.

Jemberie M (2017): Effects of NPS fertilizer rate and irrigation frequency determination method on the growth and tuber yield of potato (Solanum tuberosum L) in Koga Irrigation Scheme, Northwestern Ethiopia (M.Sc. thesis). Bahir Dar University, Ethiopia.

Mekashaw M (2016): Assessment of farmer's production practices and effects of different rates of NPS fertilizer on yield and yield components of potato (Solanum tuberosum L) variety under irrigated farming system in Dessie Zuria Woreda, Amhara Region, Ethiopia (MSc thesis). Bahir Dar University, Ethiopia.

Minstry of Agriculture and Natural Resource (2013): Ethiopia is transitioning into the implementation of soil test based fertilizer use syste. www.moa.gov.et/documents/93087/.../ be8d5386-e5fb-4ca3-8ff0-d295bc603e70

Shiferaw H (2014): Digital soil mapping: Soil fertility status and fertilizer recommendation for Ethiopian agricultural land (Conference paper). Addis Ababa, Ethiopia.

Response of Chickpea (*Cicer arietinum*) to *Rhizobium* Inoculation and Blended fertilizer Rates in Laelay Maichew Woreda, Central Zone of Tigray

Kiros Wolday* and Atsede Teklu

Tigray Agricultural Research Institute, Axum Agricultural Research Center, P.O.Box 230, Axum, Tigray, Ethiopia

*Correspondence: kiroswolday@gmail.com

Abstract

Low soil fertility is one of the limiting factors for low productivity of chickpea in Central Zone of Tigray. Field experiment was therefore, conducted for two consecutive years (2016-2017) in Laelay Maichew (Hatsebo) to evaluate the effects of NPSB fertilizer and *rhizobium* inoculation on yield and yield components of chickpea. The experiment was laid out in a split plot design with three replications. *Rhizobium* inoculation was assigned to the main plots with two levels (with and without *rhizobium* inoculation) and NPSB fertilizer rates in sub plot with seven levels (0, 25, 50, 75, 100, 125 and 150 kg ha^{-1} NPSB). Data collected were subjected to the analysis of variance (ANOVA) using SAS software. A combined analysis of variance showed a significant interaction effects of NPSB and *rhizobium* inoculation on chickpea yield and yield components (P<0.05) across the two years. The highest number of pods per plant (76.8) was recorded from from plots that received 125 kg ha^{-1}NPSB when chickpea was inoculated Highest grain yields (3609 kg ha^{-1}) were obtained from the application of 150 kg ha^{-1} and 125 kg ha^{-1} NPSB (3514 kg ha^{-1}) along with *rhizobium* inoculation. Maximum marginal rate of return (4106.68%) was gained when chickpea was inoculated with rhizobium along with 125 kg ha^{-1} NPSB application. From the present study, it canbe concluded that with the application of 125 kg ha^{-1} NPSB along with *rhizobium* inoculation would be the optimum treatment combination for enhancing chickpea yield and better profitability in soils with low level of available plant nutrients (NPSB).

Keywords: Chickpea, marginal rate of return, NPSB, *Rhizobium* inoculation, yield

Introduction

In Ethiopia pulses are among the various crops produced in all the regions of the country after cereals [Central Statistical Agency (CSA), 2018]. In 2017/18 in Ethiopia, pulses were cultivated in about 1.6 x 10^6 ha with annual estimated production of 2,978,588 tons (CSA 2018). Among the pulses crops, chickpea is an important annual crop. It is only cultivated species of genus *Cicer*. Chick pea is the world's third most important food legume next to haricot bean and soybean (Namvar and Sharifi 2011). Globally it was cultivated on area of 13.65 million ha with production of 13.10 million tons [Food and Agriculture Organization Statistical Datases (FAOSTAT), 2016]. It is grown in 35 countries of the world. India, Turkey, Pakistan, Iran, Mexico, Myanmar, Ethiopia, Australia, Spain, Canada and USA are top ten chickpea producing countries. Ethiopia contributed around 3% of the global chickpea production. In Africa, Ethiopia is the leading chickpea producer and ranked third in its production next to faba bean and haricot bean Food and Agruculture Data Bases (FAOSTAT) (2012).

Chickpea is a relatively cheap source of protein (20–23% in the grain), energy (carbohydrates, 40%), oil (3–6%) (Gil et al 1996) and minerals [Mg (magnesium, potassium (K), phosphorus (P), iron (Fe), Zinc (Zn) and manganese (Mn) (Ibrikci et al 2003) and β-carotene (Milan et al 2006)] in the developing world. Chickpea contributes significantly to sustainability of cereal-legume cropping systems, increasing the yield of cereals through enhancing the soil nitrogen (N) and breaking the disease cycles of important cereal pathogens (Pande et al 2011). However its productivity is low (1630 kg ha^{-1}) in Tigray compared to the national average (2053 kg ha^{-1}) in Ethiopia (CSA 2018) and very much below the potential of the crop.

Moisture stress (drought) mainly terminal drought, decline in soil fertility, diseases (dry root rot, wilt) and insect pests (pod borer and cut worm) are the major constraints for low productivity of chickpea. Declining in soil fertility is one of the constraints contributing for low chickpea production and productivity. Many of the soils in Ethiopia are deficient in N, P, K, sulfur (S) [Ethiopian Soil Information System (EthioSIS), 2014]. Moreover, soil fertility declining is aggravetaed due to intensive cropping and unbalanced use of fertilizers by the farmers. Therefore, balanced fertilization is needed for optimum growth and production of crops including chickpea.

In the study area, use of fertilizer was focused mainly on the use of N (urea) and phosphorous di-ammonium phosphate (DAP) for almost all crops. Such unbalanced application of plant nutrients might have aggravated the depletion of nutrient elements in soils including the recently identified S and micronutrient (B). Hence, the yield gap in pulses in general and chickpea in particular could be fulfilled through combined application of biofertilizers (rhizobium inoculants) and blended fertilizers along with improved varieties. There is also a need to consider the relative cost and profitability of these technologies with the respect to their adoption by small-holder farmers. This study was therefore initiated to evaluate the sole and comined rhizobium and blended (NPSB) fertilizer application on yield and yield components of chickpea. It was hypothesized that application of optimum NPSB fertilizer rates combined with rhizobium inoculation would improve yield and agronomic traits of chickpea in the study area.

Materials and Methods

Description of the study site

The experiment was conducted on a Vertisol at *Hatsebo* experimental site of Axum Agricultural Research Center. The experimental site is located 5 at 14°6’46”N and 38°46’3” E and attitude of 2084 meter above sea level. It is situated in the northern semi-arid tropical belt of Ethiopia where tef, chickpea, wheat and faba bean are commonly grown. Chickpea is an important crop in the area both economically and ecologically. The rainy season is mono modal concentrated in one season from July to September and receives from 400 to 800 mm rainfall per annum.

Experimental design, treatments and procedures

The experiment was carried out for two years (2016– 2017) during the rainy seasons. The experiment was conducted in a split plot design with three replications at Axum Agricultural Research Station (*Hatsebo* site) and sown at mid August. The main factor was *Rhizobium* inoculation with two levels (inoculated and uninoculated). The sub-plots factor was blended fertilizer rates with seven treatments (0, 25, 50, and 75,100,125,150 kg NPSB ha^{-1}). The experiment was conducted in a plot size of 3 m by 2.4 m with spacings of 0.10 m, 0.30 m, 0.50 m, 1 m and 1.5 m between plants, rows, sub plots, main plots and replications, respectively.

Popular and predominant grown improved chickpea variety (*Arerti*) was used for the trial. The recommended inoculantat500 g ha^{-1} was used for chickpea inoculation. Rhizobium chickpea strain CP-M-41 was obtained from Menagesha Biotech industry P.L.C, Addis Ababa, Ethiopia. It is popular strain across the country in enhancing chickpea yield and yield components. The inoculants were prepared based on the recommended rate of 10g kg^{-1} seeds for inoculation. Before planting, 1.5 kg of Chickpea (*Arerti*) seeds was prepared for inoculation. Seeds were soaked in water for 30 minutes. Then excess water was removed from the seeds by placing in a sack. There after, sugar was applied as adhesive material to stick the inoculums in to the seeds. Finally the inoculant was applied to the seeds and dressed until the seeds showed a black color in a shade to avoid direct sun light so as to maintain the viability of the inoculum.

Blended fertilizer (NPSB) at rates of 0, 25, 50, 75,100,125,150 kg ha^{-1} were applied at the center of the row and covered with soil to avoid contact with the inoculated seeds. At seed sowing, daily laborers were grouped into two before planting was started. One group planted the inoculated seed on the other hand the other group planted the non inoculated seeds. Finally, plots planted with inoculated seeds were immediately covered with soil to avoid direct sun light.

Soil sampling, preparation and analysis

Pre-sowing surface soil samples were collected at 0-30 cm depth diagonally from 20 spots in the experimental field using an Auger. Sub samples were composited and processed for soil analysis before sowing. Composite soil samples were analyzed for organic carbon (OC), total N (Kjeldahl method) and available soil P (Olsen method). Particle size was determined following the hydrometer method. Cation exchange capacity (CEC), electrical conducrivity (EC) and soil reaction (pH) were also measured using standard laboratory procedures followed by Shire Soil Research Center.

Agronomic data collection

Days to 90% maturity was recorded for all the plots when 90% of the plot was ready for harvesting when the foliage color becomes yellowish, lower pods starting shedding pods and seeds harden. At harvesting time, plant height and number of pods plant^{-1} were estimated from randomly tagged six plant samples in each plot. Harvesting was done from the central six rows. Threshing was done manually after a week. Grain yield of the inner 6 rows was measured by using sensitive balance and converted to kg ha^{-1}. Grain yield of each plot was adjusted to 12% seed moisture content. Finally, 100 seed data were weighed by counting 100 seeds from each plot by using electronic sensitive balance.

Statistical analysis

All collected data were subjected to the analysis of variance (ANOVA) using the Statistical Analysis System (SAS) computer program, version 9.1 (SAS 2002). Error variance of the individual years was tested for homogeneity. Treatment means were compared using least significant difference (LSD) at 5% probability level (Petersen 1994).

Partial budget analysis

Partial budget analysis of the *rhizobium* and blended (NPSB) fertilizer treatments were performed on the basis of prevailing market prices and according to CIMMYT (1988]. The partial budget analysis was performed to assess treatment combinations that would give acceptable returns at low risk to farmers. All costs and benefits were calculated on hectare basis in Ethiopian Birr (ETB). Variable costs (fertilizer and *rhizobium*, application and transport costs) were considered for partial budget analysis. Mean grain yield of the two years result were used for partial budget analysis. The average grain yield was adjusted to 10% downwards to reflect the difference between the experimental yield and the yield farmers will expect from the same treatment.

Results and Discussion

Experimental soil selected physical and chemical properties

Selected soil physical and chemical properties of the experimental site before planting are indicated in Table 1. The soil textural class is clay. The soil pH was neutral and non-saline (EthioSIS 2014). The soil pH is in optimal pH range for most plants. Soil OC and total N were low according to the rating of Tekalign et al (1991). Available P was in the marginal level while CEC was high according to the rating of Landon (1991).

Table 1. Physico-chemical properties of the experimental site soil before planting (0-30cm)

Soil characters	Values
Clay (%)	66
Sand (%)	12
Silt (%)	22
Textural class	Clay
Soil pH	7.2
OC (%)	0.67
Total N (%)	0.06
Available P (mg kg^{-1})	10.28
CEC (meq100 g^{-1} soil)	58.4
EC (dS m^{-1})	0.986

Notes: CEC: cation exchange capacity; EC: electrical conductivity; N: nitrogen; P: phosphorus; OC: organic

Effect on yield and yield components

The interaction effects of *rhizobium* inoculation and NPSB are presented in Tables 2, 3 and 4. Most of the parameters were significantly affected by the combined application of *rhizobium* and NPSB in chickpea. Analysis of variance result showed that significant differences were obsereved among the majority of yield and yield components of chickpea for the interaction effect of NPSB and *rhizobium* inoculation. There was significant ($p<0.05$) interaction effects of rhizobium inoculation along with NPSB application on 90% days to maturity in a separate year and combined over years. A significant and increasing trend was observed in 90% days to maturity with increasing NPSB and *Rhizobium* fertilizer levels. The shortest days to maturity (108.33) was recorded in the untreated check. On the contrary, the longest days to maturity (113) was observed in the maximum fertilizer doses and inoculation across the two years (Table 4). This could be attributed to the high N due to the increased N-in the higher fertilizer rates and able to fix of atmospheric N due to r*hizobium* inoculation. Abdula (2013) reported the delay in maturity recorded at the maximum fertilizer dose combined with rhizobium inoculation.

Table 2**.** Effect of inoculation and NPSB application on chickpea yield and yield components in Laelaymaichew (Hatsebo), in 2016

Ino*NPSB (kg ha^{-1})	90% DTM	PH (cm)	NPPL	GY (kg ha^{-1})	HSW (g)
0*0	104e	33.8e	52e	1625.7f	25e
0*25	106bcd	35.93cde	55.2de	1779.8ef	25.5de
0*50	105.67cde	36.53cde	53.5de	2075.8de	25.13e
0*75	105de	37.2bcd	65.47b-d	1821.3ef	25.7cde
0*100	106.67a-d	36.97bcd	73.33a-d	2653.8c	26.87ab
0*125	106.33bcd	38.27abc	77.6abc	2256.9cd	27.07ab
0*150	107.33abc	37.87b	75.2abc	2522.1c	26.73abc
1*0	105de	34.47de	61.37cde	1670.2ef	25.8cde
1*25	105de	36cde	63.6cde	2284.7cd	25.4e
1*50	105.33de	37.07cd	69.4b-e	2397.9cd	26.53bcd
1*75	106.67a-d	37.73bc	75.6abc	3349.8b	26.6bc
1*100	107.67ab	38.73abc	92.7a	3210.9b	27.27ab
1*125	107.33abc	39.07ab	85.2ab	3626.7ab	27.37ab
1*150	108.33a	40.99a	78.6abc	3785.1a	27.67a
Grand mean	106.17	37.19	69.91	10.01	26.33
LSD (5%)	1.67	2.93	19.98	419.3	1.04
CV (%)	0.94	4.7	17.09	10.01	2.96

Ino indicates for Rhzobium inoculantion; 0= uninoculated, 1= inoculated with rhizobium; DM= days to maturity; PH= plant height; NPPL= number of pods per plant; GY=grain yield; HSW=hundred seed weight. Means followed by the same letter(s) with in a column are not significantly different at P = 0.05

With regard to the plant height, the analysis of variance test showed a significant statistical difference ($P<0.05$) among the interaction effect of rhizobium inoculation and NPSB application in the single year as well as over years. The highest plant height (40.40 cm) was obtained from the interaction effect of *rhizobium* inoculation and NPSB application over the two years (Table 4) and the shortest plant height (32 cm) was recorded from the untreated check. This could be attributed to the high N source obtained from the fixed N- due to inoculation of r*hizobium* inoculants as well as maximum vegetative growth of the plants under higher N availability from the higher NPSB levels.

Number of pods per plant was significantly ($P \leq 0.05$) influenced by combined effect of *rhizobium* inoculation and NPSB levels in the separate years as well as across the two years (Tables 2, 3 and 4). Significantly highest number of pods per plant was counted from the combined effect of rhizobium inoculation and 125 kg NPSB ha^{-1} (65.13) compared to the control (37.67) over the two years (Table 4). This result revealed that the combined application of *rhizobium* and NPSB could be the optimum levels to obtain the higher number of pods per plant.

Table 3. Chickpea yield and yield components as influenced by inoculation and NPSB application in Laelay maichew (Hatsebo), 2017

Ino*NPSB (kg ha^{-1})	DTM	PH (cm)	NPPL	GY (kg ha^{-1})	HSW (g)
0*0	112.67a	32e	37.67d	1357.3f	24.97b
0*25	113.33a	33.4de	44.27cd	1483.2ef	25.4ab
0*50	114ab	34.33cde	45.9bcd	1851.7d	25.37ab
0*75	115ab	34.87cde	47.8bcd	1937.6d	25.5ab
0*100	114.67abc	34.27cde	46.6bcd	2013.9d	25.7ab
0*125	113.67bc	37.2abc	55.33abc	2029d	25.3ab
0*150	115bcd	36.8abc	53.33abc	2711.7c	25.17b
1*0	114bcd	34.47cde	46.2bcd	1451.1ef	25.13b
1*25	114bcd	36bcd	51.93bc	1729.4de	25.47ab
1*50	115bcd	35.27cd	52.73abc	2980.7bc	25.83ab
1*75	114cd	36.47bcd	56.3abc	3151.6ab	26.46a
1*100	115.67bcd	38.4ab	57.9ab	3332.2a	26.03ab
1*125	116.33bcd	38.6ab	65.13a	3401.9a	25.77ab
1*150	117.67bcd	39.8a	57.2abc	3433.1a	25.97ab
Grand .mean	114.64	35.84	51.31	2347.46	25.57
LSD (5%)	2.62	3.08	13.19	308.07	1.18
CV (%)	1.36	5.14	15.37	7.84	2.75

Ino indicates for Rhzobium inoculantion; 0= uninoculated, 1= inoculated with rhizobium; DM= days to maturity; PH= plant height; NPPL= number of pods per plant; GY=grain yield; HSW=hundred seed weight. Means followed by the same letter(s) with in a column are not significantly different at P = 0.05

In relation to grain yield, analysis of variance revealed significant difference ($P<0.05$) among the combined application of rhizobium and NPSB. Application of NPSB and r*hizobium* inoculants at the same time had synergistic effect on the yield of chickpe tha had increased the yield. All the treatments gave higher number of pods per plant over the control. Application of 125 kg/ha NPSB along with *rhizobium* inoculation showed 134% yield increment compared to the untreated check (control). Synergetic and positive response of *rhizobium* inoculation and DAP was reported in Birhanu and Pant (2012) in chickpea grain yield at shoa robit area.

Table 4. Combined mean value of chickpea yield and yield components as influenced by the application of *rhizobium* inoculation and NPSB in Laelay maichew (Hatsebo) 2016-2017

Ino*NPSB (kg ha^{-1})	90% DTM	PH (cm)	NPPL	GY (kg ha^{-1})	HSW (g)
0 *0	108.33	32.9f	43.5f	1501e	24.98e
0 *25	109.67	34.67ef	49.73ef	1631.5de	25.45cde
0 *50	109.83	35.43cde	49.70c-f	1903.7cde	25.25de
0 *75	110	36.03ed	56.63c-f	1956.7cd	25.6bcde
0 *100	110.67	35.62de	59.97b-e	2191.8bc	26.28abc
0 *125	110	37.73bc	66.47a-e	2261.3bc	26.18a-d
0 *150	111.17	37.33bcd	64.27def	2616.9e	25.95a-d
1 *0	109.5	34.47ef	51.95def	1517.6e	25.47cde
1 *25	109.5	36cde	57.77c-f	1640.4de	25.43cde
1 *50	110.17	36.17cde	58.73b-f	1910.7cde	26.18a-d
1*75	110.33	37.1bcd	65.95a-d	2200.7c	26.53ab
1*100	111.67	38.57ab	70.18abc	2489.9b	26.65a
1*125	111.83	38.83ab	76.8a	3514.3a	26.57a
1 *150	113	40.40a	73.83ab	3609.1a	26.82a
Grand .mean	110.4	36.53	60.39	2210.39	25.95
LSD (5%)	NS	2.11	15.31	437.94	0.94
CV (%)	4.4	5.01	22.2	17.21	3.16

Ino indicates for Rhzobium inoculantion; 0= uninoculated, 1= inoculated with rhizobium; DM= days to maturity; PH= plant height; NPPL= number of pods per plant; GY=grain yield; HSW=hundred seed weight. Means followed by the same letter(s) with in a column are not significantly different at P = 0.05

Table 5. Net benefit analysis of NPSB application and *rhizobium* inoculation on chickpea grain yield in Hatsebo (2016-2017)

Ino*NPSB (kg ha^{-1})	Yield (kg ha^{-1})	adj yield	Gross field benefit	Total variable cost	Net benefit
0*0	1501	1350.9	29719.8	0	29719.8
1*0	1517.6	1365.84	30048.48	40	30008.48
0*25	1631.5	1468.35	32303.7	482.19	31821.5125
1*25	1640.4	1476.36	32479.92	522.19	31957.7325
0*50	1903.7	1713.33	37693.26	964.38	36728.885
0*50	1910.7	1719.63	37831.86	1004.38	36827.485
0*75	1956.7	1761.03	38742.66	1446.56	37296.0975
1*75	2200.7	1980.63	43573.86	1486.56	42087.2975
0*100	2191.8	1972.62	43397.64	1928.75	41468.89D
1*100	2489.9	2240.91	49300.02	1968.75	47331.27
0*125	2261.3	2035.17	44773.74	2410.94	42362.8025D
1*125	3514.3	3162.87	69583.14	2450.94	67132.2025
0*150	2616.9	2355.21	51814.62	2893.13	48921.495D
1*150	3609.1	3248.19	71460.18	2933.13	68527.055

0= inoculated; 1= inoculated; D = Dominated (any treatment that has net benefit less than or equal to that of a treatment with lower cost that vary is dominated)

Hundred seed weight (HSW) analysis of variance test showed a significant statistical difference (P<0.05) in the interaction between *rhizobium* inoculation and NPSB application (Table 4). The highest hundred seed weight (26.46 g) was recorded with inoculation *Rhizobium* inoculants along with 75 kg NPSB ha^{-1}, followed by *rhizobium inoculation* along with 100 kg NPSB ha^{-1} which was significantly higher than control.

Partial budget analysis of combine effects of *Rhizobium* inoculation and NPSB fertilizer applied indicated that inoculation with 125 kg NPSB ha^{-1} was the most economical with maximum marginal rate of return (4106.48%) followed by inoculation along with 75 and 100 kg NPSB ha^{-1} respectively (Table 5; Table 6).

Table 6**.**Mariginal rate of analysis of NPSB application and *rhizobium* inoculation on chickpea grain yield in Hatsebo (2016-2017)

Ino*NPSB (kg ha^{-1})	Adjusted yield	Gross field benefit	Total variable cost	Net benefit	MRR%
0 *0	1350.9	29719.8	0	29719.8	_
1*0	1365.84	30048.48	40	30008.48	721.7
0 *25	1468.35	32303.7	482.19	31821.5125	410.01
1 *25	1476.36	32479.92	522.19	31957.7325	340.55
0*50	1713.33	37693.26	964.38	36728.885	1078.99
1*50	1719.63	37831.86	1004.38	36827.485	246.5
1*75	1980.63	43573.86	1486.56	42087.2975	1090.82
1 *100	2240.91	49300.02	1968.75	47331.27	1087.54
1 *125	3162.87	69583.14	2450.94	67132.2025	4106.48
1 *150	3248.19	71460.18	2933.13	68527.055	289.28

0= inoculated; 1= inoculated; Marginal rate of return = Marginal net benefit x 100/Marginal cost; Current Price of chickpea= 22 birr/kg

Conclusion and Recommendation

The interaction effect of NPSB and inoculation for most of the parameters were significant in each year and across the two years. The highest grain yield of chickpea was recorded from the inoculated seed planted with the application of 125,150 and 100 kg ha^{-1} blended (NPSB) fertilizers, respectively in decreasing order over the two years at Hatsebo research site in Laelay maichew Woreda .However, maximum marginal rate of return were obtained from 125, 75 and 100 kg ha^{-1} NPSB along with *rhizobiaum* inoculation. Therefore, 125 kg ha^{-1}NPSB with *rhizobiaum* inoculation is recommended as optimum treatment combination for enhancing chickpea grain yield and profitability in soils having low NPSB availability.

Acknowledgments

We would like to thank all crop core process researchers of Axum Agricultural Research center who helped us during the experiment implementation.

References

Abdula IA. (2013): Agronomic and symbiotic characteristics of chickpea, Cicer arietinum (L.), as influenced by Rhizobium inoculation and phosphorus fertilization under farming systems of Wolaita area, Ethiopia. M.Sc. Thesis, Wageningen University.

ATA (Ethiopian Agricultural Transformation Agency) and MOA (Ministry of Agriculture) (2014): Soil fertility status and fertilizer recommendation atlas for Tigray regional state, Addis Ababa, Ethiopia.

CIMMYT (International Center for Maize and Wheat Research) (1988): From agronomic data to farmer recommendations: an economics work book. The International Maize and Wheat Improvement Center, Mexico, pp. 1-63.

CSA (Central Statistical Agency) (2018):Agricultural sample survey 2017/2018: Area and Production of Crops (Private Peasant holdings, Meher Season). Statistical Bulletin 586, Addis Ababa, Ethiopia

FAOSTAT (Food and Agriculture Organization Statistical Datases) (2012): Food and Agricultural Organization Statistical Database, Crop Production Index. Rome, Italy: FAO.

FAOSTAT (Food and Agriculture Organization Statistical Datases) (2012) (2016). Food and Agricultural Organization Statistical Database, Crop Production Index. Rome, Italy: FAO

Gil J Nadal S Luna D Moreno MT and de Haro A. (1996): Variability of some physico-chemical characters in Desi and Kabuli chickpea types. *Journal of Food Science Agriculture*, (71): 179–184.

Herrera E. (2005): "Soil Test Interpretations Guide A-122". College of Agriculture and Home Economics, New Mexico State University.

Ibrikci H Knewtson S and Grusak MA. (2003): Chickpea leaves as a vegetable green for humans: Evaluation of mineral composition. *Journal of Science Food Agriculture,* (83): 945–950.

Messele B Pant LM (2012): Effects of inoculation of Sinorhizobium ciceri and phosphate solubilizing bacteria on nodulation, yield and nitrogen and phosphorus Uptake of Chickpea (Cicer arietinum L.) in Shoa Robit Area. *Journal of Biofertilizer and Bio pesticides*, 3:129. doi:10.4172/2155-6202.10000129.

Millan TJ Clarke HJ Kadambot H Siddique HKM Gaur PM Kumar J Gil1 J Kahl G and Winter P (2006): Chickpea molecular breeding: New tools and concepts. *Euphytica*, (147): 81–103.

Pande S Sharma M Gaur PM Tripathi S Kaur L Basandrai A Khan T Gowda CLL and Siddique KHM. (2011): Development of screening techniques and identification of new sources of resistance to Ascochyta blight disease of chickpea. *Australasian Plant Pathology,* (40): 149–156.

Petersen RG. (1994): Agricultural field experiments design and nalysis. Marcel Dekker, Inc., New York.

SAS (Statistical Analysis System) (2002): Version 9.1.SAS Institute Inc., Cary, NC, USA.

Way-forward

A national workshop on blended fertilizer with a theme 'The Role of Blended Fertilizers in Enhancing Productivity and Quality of Crops in Ethiopia' was convened by Tigray Agricultural Research Institute for two days in Mekelle. In the workshop, keynote address, two invited papers, eighteen oral paper, five posters and plenary discussion on the way forward were discussed. Bread wheat, tef, barley, maize, sorghum, upland rice, chickpea, onion, tomato, hot pepper and sesame were used as test crops in the blended fertilization studies as presented by researchers. The blended fertilizer effects were comparable with the previously recommended N and P for the various crops. In some of the studies, the blended fertilizers performed better than the previously recommended NP and control treatments. However, the specific nutrient effects in the blended fertilizer are difficult to elucidate. The following researchable and non-researchable ideas are identified as a way-forward for the blended fertilizer practice and management in Ethiopia.

1. The blended fertilizer recommendations of Ethio-SIS were based on surface soil fertility assessments and didnot consider crop and soil types. The results of many blended fertilizer experiments indicated positive response to the applied fertilizers but it was not clear which element (s) in the blended fertilizer had caused the increment in yield and other yield components which calls for further future nutrient based investigation. Besides, the reason for the non-significant differences among blended fertilizer rates should further be refined, because it might be due to sufficiency of either of the nutrient levels in the soils of experimental fields that were not assessed before planting for many of the studies. Further study should focus on single nutrient based research along major agro-ecologies, soil and crop types, and landscape position.
2. The issue of blended fertilizer studies should not be considered separately but it should be taken as part of integrated soil fertility management i.e. including improved seed, other soil factors and management practices.
3. Most of the papers presented in the blended fertilizer workshop were lacking soil and crop nutrient data. Therefore, in the future, issuing mandatory protocol that provides minimum standard requirements in soil fertilizer and fertility research including soil and crop data to be collected is necessary.

4. Socio-economic and environmental impacts should also be considered when dealing with blended fertilizers. Final recommendations and conclusions should consider preferences and suggestion of farmers after their observation during field days.
5. Blended fertilizer quality assurance should be established and farmers should pay based on the amounts of nutrients available in the fertilizers.
6. Soil fertility and fertilizer research should include the whole continuum starting from soil nutrient to human nutrition.
7. Research in soil fertility and fertilizer should take into account improvement in forage production and nutrition.
8. Soil fertility and fertilizer recommendations should consider problematic soils such as acidity, salinity, and sodicity and moisture deficit dry land area.
9. International to local level platforms should be established to develop integrated soil fertility management for the different crops and soils.
10. Capacity building particularly in fertilizer science is vital. Research capacity was not built on big data analysis. Hence, there is a need for capacity building of researchers on capturing data and converting it into valuable information. Strengthening the soil research centers (Mekelle Soil Research Center, Shire Soil Research Center and Humera Soil Sub-Research Center) with budget, soil laboratory , human capacity, transportation and other new technologies is important in order to take the lead of soil fertility and fertilizer research
11. Unorganized blended and other fertilizer studies are currently being carried out in different places by different professionals using different methods and procedures that led to resource wastage and erroneous conclusions based on insufficient data and information. Therefore, collaboration among different disciplines, organizations and professionals working on fertilizer studies is needed.
12. Linkage between the research and development partners should be strengthen for the development of technologies and packages on fertilizers and integrated soil fertility management. Research should take a lead for adoption and generation of fertilizers and integrated soil fertility management technologies. Site-specific and wider area recommendation should also be packaged.

13. The contribution of the research findings presented on the workshop to the national initiatives is tremendous. Nationwide collaboration and working together is vital since the decision on fertilizers comes from the center. Next meeting on fertilizer should be based on the lesson learned from Tigray and the key issues identified during the workshop.

ISBN 978-99944-77-46-3