Tigray Agricultural Research Institute
Agricultural Growth Program-II

Adaptation and Generation of Agricultural Technologies


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Tigray Agricultural Research Institute
Agricultural Growth Program-II

AGRICULTURAL
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Adaptation and Generation of Agricultural Technologies

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The research tasks are not also being done without the great demand of farmers to adopt new agricultural technologies and practices; there for our gratitude as institute and the AGP program would like to acknowledge the workaholic farmers that have been working with the program. Eventually, the collaborative TARI management staff and TARI/AGP-II coordination staff are among those who need to be appreciated and acknowledged for their unreserved technical and financial monitoring, evaluation and support.

Forward

Agriculture have been implemented through identifying and prioritizing commodities for food security, climate smart and excess production for commercialization and source material for industry which would be as a great role for supporting the transformation agenda of the country. For this reason, the government of Ethiopia designed an agricultural growth program one and two to support both the research and extension in five components. The research component deals on technology generation/adaptation, technology demonstration, technology multiplication and human and physical capacity building. Since the launching period on 2016 the institute has generated/adapted and demonstrated several technologies to the public extension. This 2019 publication consists of the completed research activity done by the AGP-II mandate centers that could be as source of information and evidence to support our agriculture to improve production and productivity and it will also be as a resource for further scientific studies and developmental works.

The extension will also use as evidence and guide for further scale up and package implementation in supporting the farmers. As a research we recommend every stakeholder who would like to support the agriculture should start with assessing and having information on what have been done and written in the major commodities of the region so that the duplication of resource could be minimized and the technical efficiency of support could also be improved using the justification given by agricultural researchers.

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Preface

Agricultural growth program has been implemented since 2015; and have successfully achieved about 22 technologies through generation/adaptation research activities. Most of the technologies have also been pre-demonstrated to the public extension through than FREGs established. As the third component of the research to produce 3000 pre-basic seed, it is achieved and disseminated to beneficiaries through the seed system established in the region. In this completed proceeding, technologies generated/adapted and pre-demonstrated are compiled in the intention for the extension to adopt them and have evidence on the advantage of the research done so fare in improving the production and productivity of the selected mandate commodities of AGP-II. This publication will also be useful as a base lines and reference for further studies and related projects. I would like to convey my massage to the research institute, extension bodies and stakeholders who are working on improving the production and productivity of the commodities included in this document; to begin with assessing what is done and to take the recommendations given by the researchers to popularize the findings. No matter how AGP-II exists or not, the bureau of agriculture and the institute need to take the outputs into considerations for further planning and policy arrangements. I would also like to congratulate to every farmers of the AGP-II mandate districts, TARI researcher, expert and DAs for their unreserved contribution for the successful implementation and completion of these research outputs.

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1.1. Evaluation of Sesame (Sesamum indicum L.) Land Races for Non-Shattering Traits and Agronomic Performance in North Western Tigray

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Abstract

Sesame (*Sesamum indicum* L.) is one of the most popular oil crops grown in Ethiopia and the world mainly for its oil rich seeds. Aside from the popularity of the crop in Ethiopia, productivity is low due to several reseaons. The objectives of the study were to select better performing sesame accessions and to quantify their shatter resistance abilities. A total of seventy eight accessions collected from different parts of Ethiopia were included in this study along with Setit-1 and Setit-2 as standard checks. Augmented design was used where the checks being replicated along each incomplete block. The results of the study showed that there is significant variability among the tested accessions for major traits like flowering, maturity, number of capsules and seed yield. Accesion 28318 and accesion 28313 were ther easrliest in days to flowering where as accesion 28328 was the latest with 55 days to flowering. The result shown that there was actually a huge difference in earliness among different sesame accesions. Similarly accesion 202370 was the earliest to mature with 84 days whereas, accesion 235905 and accesion 28320 scored the highest days to maturity (103) followed by accession 17697 102 days. Accession 28315 gave the highest seed yield of 1266 kg/ha. Significant variation was observed regarding the seed retention capacities of the tested sesame accessions in which, accessions 241342 and 17703 scored the highest mean seed retention percentages of 89.72 and 88.58 respectively. The standard checks (Setit-1 and Setit-2 scored below average mean seed retention percentage in the study. The study is helpful to develop and deploy sesame varieties with shattering resistance, improved yield and good agronomic performance in the study area and other similar agro ecologies.

Key words: Sesame, Shattering, Acessions, *Sesamum indicum*

Introduction

Sesame (*Sesamumindicum*L.) is one of the oldest and most important oil seed crops widely grown in tropical and subtropical regions around the world and is cultivated for its oil-rich seeds, which grow in pods (Weiss 1983). Sesame is grown in more than seventy countries worldwide. According to FAO (2014), Tanzania, India, China, Sudan, Nigeria, Myanmar, Burkina Faso and Ethiopia are the greatest sesame producers, respectively covering 70.88 % of the world production. Sesame is one of the major indigenous oilseeds displaying considerable diversity in Ethiopia. Annually sesame accounts for about 44 % of the total acreage and 34% of the gross production of the majoroilseeds cultivated in the country (CSA 2013)

Sesame, locally called ‘Selit’, is a valuable export crop in Ethiopia. It grows in almost all regions of the country with analtitude of less than 2000m above sea level (Yebiyo 1985; Adefris et al. 2011) and is a well-established crop in Amhara, Tigray and Oromia regions, respectively. Reports on peasant holdings in sesame showed that 89.95% (2466503.09 tons) of the Ethiopian sesame produce comes from Amhara (48.84%), Tigray (24.52%) and Oromia (16.59%) regions (CSA 2015). In Ethiopia sesame is grown chiefly for export (more than 95%) and direct consumption (5%) (Anera 2009) The sesame seed is rich in good quality edible oil (up to 60%) and protein (up to 25%) (Brar and Ahuja 1979).The oil is in demand in the food industry because of its excellent cooking quality, flavor, and stability. In Ethiopia, sesameoil and seed are put to a great variety of uses. The oil, besides as a cooking medium, is also used for anointing the body.The oil cake which is rich in calcium is used as feed. The seed is used in the preparation of different foods (stew calledwet, a sauce for porridge, snacks, flavoring, sweets and beverages) (Adefris et al. 2011).

The majority of the world's sesame (probably over 99%) have shattering capsule, and most of the harvest is manual (Langham 2001). Shattering of capsules at maturity has posed serious problem in sesame production worldwide (Ashri 1994) and can account for up to 50% seed loss during harvest. Indehiscent capsules and superior architecture are amongst the basic objectives laid down for sesame breeding and the degree of dehiscence is a cultivar characteristic and is of great importance for mechanized harvesting (Yadava et al. 2012; Van Zanten 2001).

Besides the shattering physical shattering characteristics of sesame, one of the major reasons for their low yield in most sesame landraces is their of indeterminate growth habit, in which the plant flower continuously and bear dehiscent capsules Ashri (1998). The plant continues to flower even when the earliest set capsules at the lower portion of the plant are mature which results in non- synchronous maturity of the capsules and seed shattering in the field Weiss (1971) This can be avoided by developing sesame genotypes with determinate growth habit. Although determinate growth habit of sesame was discovered many years ago, it has not been adopted because of many pleiotropic effects associated with the character including severe reduction of plant height, twisted stem and semi sterility Uzun et al. (2013). A few closed capsule mutants were developed earlier to reduce seed loss, but due to difficulty in seed release during threshing the quality of the seed decreases Uzun et al. (2004). On the other hand semi shattering sesame genotypes bearing capsules with higher seed retention capacity will delay opening of mature capsules in the field and release seeds easily on threshing Langham (1998). Therefore, development of semi shattering genotypes with good seed retention capacity at maturity will be useful in maintaining seed quality and help in reducing the yield loss due to capsule shattering in the field. For the development of semi shattering sesame genotypes, the capsule characters related to seed retention need to be identified and analyzed for their effect on seed yield.

Shattering is the most important yield limiting factor of sesame in Ethiopia. Shattering of capsule eat maturity leads to poor harvest index and sometimes when it is combined with shortage of labor during harvesting lead to complete loss of yield. In Ethiopia, cultivated sesame cultivars have indeterminate flowering habit which will continue flowering as long as moisture and nutrients are available. As the flowering continues, the early capsules dry down, open and lose their seed. This plant character makes it difficult its harvest by combine. Because of this problem, in Ethiopia, it is grown and harvested manually (Tadele 2005; Adefris et al. 2011; WARC 2014; MoARD et al. 2015). Therefore, the development of productive non- shattering cultivars is critical for cultivation of sesame in more intensive agriculture with mechanized harvesting. Thus, a study was conducted to select better performing sesame accessions and to quantify their shatter resistance abilities sesame land races collected from different parts of Ethiopia.

Materials and Methods

Site description

The experiment was conducted at the experimental station of Shire-Maitsebri agricultural research center (SMARC) based at Sheraro sub-station during 2018 cropping season. The station is located at an altitude of 1006 m.a.s.l., 14o 24' 00" N latitude, 37o 56' 00" E longitude. The area is characterized hot to warm semi-arid low land plains, with a Monomodal rainfall pattern. The mean total annual rainfall during the growing season was about 675.8 mm. Average annual rainfalls for the last previous 10 years was 683.05mm and ranges from 427.7mm to 835.6 mm. The mean maximum and minimum air temperature of the site was 40.5^{0}C and 13.3^{0}C respectively. The soil at the test site was clay and other soil properties are listed in Table 1.

Table1. Soil physical and chemical properties of the study area in 2018 at Sheraro, Ethiopia

pH	Total N (%)	Pav (ppm)	K Ex (PPm)	CEC (meq/100g)	OM (%)	Particle size distribution			
						Sand (%)	Silt (%)	Clay (%)	Textural class
7.16	0.120	27.295	618.4	21.9	1.136	14	21	65	Clay

Source; Shire Soil Research Center (un published data)

Plant materials and experimental design

Seventy-eight sesame (*Sesamum indicum* L.) landraces/accessions were included in the study with two standard checks (Setit-1 and Setit-2). Augmented design was used in the study where the two standard checks were replicated across the 10 incomplete blocks. All necessary agronomic inputs were applied according to sesame recommendations for sesame production for the area.

Assessment of capsule shattering

Assessment of shattering resistance was conducted following the pattern of Maneekao et al. (2001). For each treatment, the number of seeds per mature capsule (brown capsule when it is upright), the number of seeds left per capsule when it is inverted and the size of opening of the capsule was determined.

To get number of seeds per capsule in upright position, a mature capsule was plucked gently and then placed in an inverted position with a sheet of paper underneath. The sheet is to hold any seed that escaped from the capsule when inverted.

The number of seeds per capsule in inverted position was calculated as the number of seeds left in the capsule after inverting the capsule.

The number of seeds per capsule in upright position is the number of seeds in inverted position plus the seeds that fall on the sheet as indicated by the formula below.

U = I+ E

Where U = number of seeds in upright position; I = number of seeds in an inverted position; E = seed that escaped during inversion of the capsule.

The shatter resistance was classified by using the concept of Langham as described by Wongyai et al. (2001). Yield and yield components related data are collected on plot basis and analysed using GENSTAT statistical packange version 18. Mean comparision was conducted jusing fishers unprotected test at 0.05% confidence interval.

Results and Discussion

Among the tested accessions, the earliest in terms of days to flowering was accesion 28318 and accession 28313 (39 days) followed by accession 202370 (40 days) while the late genotype to flower was accession 28328 (55 days). The result showed that there is considerable difference in earliness among different sesame accessions collected from different parts of Ethiopia. Similarly accession 202370 was the earliest to mature (84 days) followed by accession 28313 and 28318 with 86 days to mature whereas, accession 235905 and accession 28320 scored the highest days to maturity (103) followed by accession 17697 with 102 days.

Yield determining factors like the numbers of capsules in a plant are very important in sesame improvement. In this study the highest score for this trait was recorded from accession 9888 which is average of 195 capsules per plant. Accessions 241339, 17700 and 17702 scored 156.6, 156.6 and 154.2 average number of capsules per plant. Regarding to seed yield per plant, accession 28315 gave the highest seed yield of 1266 kg/ha while accessions 202370 and 202370 were also among the highest yielders with 1266 kg/ha and 1049 kg/ha seed yield respectively. Similar results were obtained by the studies of Naim et al., 2010 were high yield obtained in some particular cultivars might be as result of more number of capsules per plant and number of seeds per capsule.

Table 2. Agronomic performance of different sesame (*Sesamum indicum*L.) landraces in 2018 cropping season at Sheraro, Ethiopia

Trt code	Trts name	DTF	DTM	NCPP	Yld (kg/ha)	Trt code	Trts name	DTF	DTM	NCPP	Yid (kg/ha)
1	28318	39.0 a	86.0 a	44 f-k	457.0 e-m	30	9691	45.0 a-h	90.0 a-j	84.8 c-j	443 e-m
2	28313	39.0 a	86.0 a	79.4 c-k	623 d-l	31	17693	46.0 a-i	90.0 a-j	91.2 c-i	412 ef-m
3	202370	40.0 ab	84.0 a	111.2 b-e	1049 bc	32	17706	46.0 a-i	86.0 a	50.4 e-k	488 ef-m
4	241315	41.0 abc	85.0 a	81 c-k	623 d-l	33	17709	46.0 a-i	91.0 a-k	68.2 c-k	327 j-m
5	241340	41.0 abc	85.0 a	22.2 k	379 g-m	34	28310	46.0 a-i	93.0 a-m	34.4 ijk	350 i-m
6	17713	41.0 abc	87.0 ab	70 c-k	600 d-m	35	28324	46.0 a-i	85.0 a	91.4 c-i	647 c-l
7	17696	41.0 abc	87.0 a-d	71 c-k	480 e-m	36	17700	46.0 a-i	91.0 a-k	156.6 ab	410 e-m
8	28315	41.0 abc	87.0 a-d	73.8 c-k	637 c-l	37	235769	46.0 a-i	90.0 a-j	49.4 fg-k	1273 a
9	24136	41.0 abc	89.0 a-i	67.2 c-k	478 e-m	38	28312	46.0 a-i	90.0 a-j	56.4 d-k	600 d-m
10	Setit-1	42.7 a-e	87.8 a-e	55.2 ijk	468.1 h-m	39	9687	46.0 a-i	90.0 a-j	86.4 c-j	459 e-m
11	Setit-2	41.1 a-d	87.8 a-e	55.0 ijk	488.6 g-m	40	28322	46.5 a-i	87.0 abc	52.6 f-k	499.5 e-m
12	17712	43.0 a-f	89.0 a-i	125.2 bc	557 e-m	41	241320	47.0 a-i	85.0 a	83.4 c-j	714 c-k
13	241334	43.0 a-f	90.0 a-j	87.2 c-j	470 e-m	42	241330	47.0 a-i	91.0 a-k	31.4 ijk	425 e-m
14	241324	43.0 a-f	90.0 a-j	103.6 b-g	756 c-i	43	28326	47.0 a-i	85.0 a	66.4 c-k	478 e-m
15	9692	43.0 a-f	90.0 a-j	100.8 b-h	709 c-k	44	9695	47.0 a-i	91.0 a-k	41.2 h-k	467 e-m
16	216733	43.0 a-f	85.0 a	59.6 d-k	424 e-m	45	17701	47.0 a-i	91.0 a-k	68.4 c-k	573 e-m
17	241339	43.0 a-f	93.0 a-m	156.6 ab	811 c-f	46	17702	47.0 a-i	91.0 a-k	156.4 ab	1002 bcd
18	28321	43.0 a-f	86.0 a	40.6 h-k	335 i-m	47	17704	47.0 a-i	91.0 a-k	70.6 c-k	539 e-m
19	9693	43.0 a-f	87.0 a-d	26.2 jk	294 klm	48	28301	47.0 a-i	85.0 a	45.4 f-k	365 g-m
20	9694	43.0 a-f	90.0 a-j	72.2 c-k	604 d-l	49	28303	47.0 a-i	90.0 a-j	83.4 c-j	343 i-m
21	19041	44.0 a-g	84.0 a	45.0 f-k	501 e-m	50	28308	47.0 a-i	91.0 a-k	70.0 c-k	674 c-l
22	28349	44.0 a-g	88.0 a-f	34.2 ijk	396 f-m	51	9696	47.0 a-i	91.0 a-k	39.8 h-k	514 e-m
23	9020	44.0 a-g	85.0 a	46.0 f-k	541 e-m	52	9888	47.0 a-i	91.0 a-k	195.0 a	811 c-f
24	28311	44.0 a-g	85.0 a	28.6 jk	433 e-m	53	228255	47.0 a-i	91.0 a-k	40.0 h-k	829 cde
25	17705	45.0 a-h	85.0 a	104.6 b-f	494 e-m	54	28329	47.0 a-i	87.0 a-d	113.8 bcd	600 d-m
26	17707	45.0 a-h	91.0 a-k	78.8 c-k	488 e-m	55	17703	48.0 a-i	91.0 a-k	49.6 f-k	469 e-m
27	17708	45.0 a-h	90.0 a-j	60.8 d-k	500 e-m	56	241329	48.0 a-i	91.0 a-k	77.8 c-k	784 c-g
28	241341	45.0 a-h	84.0 a	40.6 h-k	477 e-m	57	17694	48.0 a-i	91.0 a-k	53.8 d-k	388 f-m
29	28302	45.0 a-h	85.0 a	67.2 c-k	554 e-m	58	17699	48.0 a-i	91.0 a-k	81.4 c-k	728 c-j

Table2. continued

Trt code	Trts Name	DTF	DTM	NCPP	Yld (kg/ha)
59	241338	48.0 b-i	88.0 a-g	52.4 f-k	418.5 g-m
60	241332	49.0 b-i	87.0 a-d	69.2 c-k	430 e-m
61	211305	49.0 b-i	91.0 a-k	37.6 ijk	350 i-m
62	241307	49.0 b-i	92.0 a-l	47.6 f-k	413 e-m
63	19043	50.0 c-i	92.0 a-l	38.8 ijk	328 j-m
64	28307	50.0 c-i	91.0 a-k	68.2 c-k	780 c-h
65	238268	51.0 f-i	96.0 b-n	65.2 c-k	392 f-m
66	211322	51.0 f-i	105.0 no	47.6 f-k	464 e-m
67	28309	51.0 f-i	97.0 f-o	48.6 f-k	423 e-m
68	24318	52.0 f-i	98.0 i-o	69.2 c-k	457 e-m
69	28320	52.0 f-i	103.0 no	50.4 e-k	340 i-m
70	241342	52.0 f-i	106.0 o	43.0 g-k	356 h-m
71	17695	52.0 f-i	98.0 i-o	53.6 d-k	549 e-m
72	235905	52.0 f-i	103.0 no	49.2 f-k	1266 a
73	17697	52.0 f-i	102.0 mno	53.0 d-k	705 c-k
74	241317	53.0 ghi	89.0 a-i	48.0 f-k	567 e-m
75	241319	53.0 ghi	90.0 a-j	123.2 bc	526 e-m
76	28314	53.0 ghi	101.0 l-o	49.2 f-k	647 c-l
77	241323	53.0 ghi	100.0 k-o	44.4 f-k	176 m
78	9896	53.0 ghi	99.0 j-o	52.6 ef-k	364 g-m
79	28327	54.0 hi	89.0 a-i	57.4 d-k	333 i-m
80	28328	55.0 i	98.0 i-o	49.4 f-k	271 lm
	F-test	Ns	**	**	**
	CV	7.4	3.6	31.8	24.7
	LSD (<0.05%)	9.79	9.38	59.8	415.7

DTF=Days to flowering; DTM=Days to maturity; NCPP=Number of capsules per plant; YLD=Seed yield ,Trt= Treatments

Shattering in terms of seed retention percent

As indicated in table below, significant variation was observed regarding the seed retention capacities of the tested sesame accessions. Difference in seed retention characteristics and capsule opening length was observed in this study. Capsule shattering resistance in a crop is likely to result from the combination of several characters.

Table-3. Mean seed retention percentage and shatter resistance scale of sesame accessions tested in 2018 cropping season at Sheraro, Ethiopia.

Acc_No	Mean seed retention %	Shatter resistance scale 1-8	Acc_No	Mean seed retention %	Shatter resistance scale 1-8	Acc_No	Mean seed retention %	Shatter resistance scale 1-8
241342	89.72	8	17693	63.77	6	211305	51.7	5
17703	88.58	8	241332	63.55	6	9020	51.27	5
17713	87.7	8	235905	63.35	6	9695	51.23	5
241339	84.3	8	17697	61.97	6	Setit-1	49.85	4
241341	82.66	8	241323	61.72	6	Setit-2	48.6	4
9696	79.14	7	17705	61.49	6	216733	48.3	4
28301	75	7	17694	60.97	6	17709	46.06	4
9687	74.95	7	19043	60.74	6	241317	45.6	4
17708	74.43	7	241319	60.53	6	28320	45.46	4
17699	73.6	7	235769	60.39	6	211322	45.38	4
24318	71.52	7	28315	60.11	6	28303	43.34	4
28312	70.73	6	28349	59.93	5	28328	43	4
28324	70.69	6	241338	59.28	5	241307	40.95	4
28314	70.54	6	17700	59.04	5	28313	39.55	3
28327	70.17	6	28321	58.36	5	241324	37.5	3
17696	68.61	6	28310	58.35	5	241334	36.75	3
28307	68.57	6	9694	56.74	5	17702	36.45	3
17707	68.27	6	28329	56.27	5	17706	34.82	3
238268	68	6	241330	55.82	5	241315	33.65	3
9896	67.84	6	241329	55.67	5	17695	30.11	2
9692	67.7	6	17712	55.59	5	28322	29.75	2
9691	67.65	6	202370	54.45	5	241320	27.13	2
17704	65.57	6	28318	54.4	5	19041	15.87	1
28311	65	6	241340	54.16	5	24136	14.77	1
28326	64.77	6	228255	53	5	28308	13.77	1
17701	64.56	6	28309	53	5			
9693	64.08	6	28302	52.57	5			

Among many characters contributing for shatter resistance in sesame, capsule opening and seed retention capacity of mature dry capsule is important Langham (1998). Information on capsule opening size, number of seeds in upright position (U); number of seeds in an inverted position

(I); seed that escaped during inversion of the capsule (E) was recorded, which indicated that mean seed retention % ranges from 89.72 to 13.77% with an overall mean of 56.9%. Accessions 241342 and 17703 scored the highest mean seed retention percentages of 89.72 and 88.58 respectively. The lowest mean seed retention percentage of 13.77 was recorded from accession 28308. The standard checks (Setit-1 and Setit-2) scored below average mean seed retention percentage in the study.

Conclusion and Recommendation

The study indicated that there is a huge variation in agronomic, yield and yielding components among Ethiopian sesame accessions. This variation should be properly exploited to develop early maturing and high yielding varieties. Interesting variation on seed retention capacities observed is a good indicator towards moderate shatter resistance. Accessions such as 241342 and 17703 helpful to develop and deploy sesame varieties with shattering resistance, improved yield and good agronomic performance in the study area and other similar agro ecologies.

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1.2. Evaluating the Efficacy of Different Insecticides in Controlling Sesame Webworm (Antigastracatalaunalis) in Western Tigray, Ethiopia,

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Abstract

Sesame (*Sesamumindicum L.*) is an annual plant that belongs to the family *Pedaliaceae* and it is one of the most export oil crops in Ethiopia. However, the production of sesame is low because of different insect pests damaged. Among the insect pest sesame webworm is one of the most important and causes a significant loss. The objective of the study was to evaluate the efficacy of different insecticides against sesame webworm. A field experiment was conducted at Humera Agricultural Research Center at three locations (Humera, Banat and Maygeba) during the main growing season in 2017 and 2018.The experiment was laid down in randomized complete block design (RCBD) with three replications. The newly released sesame variety Setit-2 was used as a planting material. Results revealed that the highest incidence, leafinjury, flower injury and capsule injury were recorded on untreated (control) as compared with chemical sprayed plots. The highest grain yield was obtained from the plots sprayed with Agro-lambacin supper315EC (417.15 kg/ha), Diaznon60%EC (413.02kg/ha), Dimethoate40%EC (407.99kg/ha), Pritacet10 EC (406.05kg/ha), Carbaryl85% WP (403.16kg/ha), and Modan5%EC (400.27kg/ha). The highest avoidable yield losses due to sesame webworm was also recorded on Agro-lambacin super 315 EC (32.33%), Diazinon60% EC (31.66%), Dimethoate40%EC (30.82%), Pritacet10 EC (30.49%) and Modan5%EC (30.07%) respectively compared to the other sprayed plots and untreated plot. The highest benefit cost ratio was obtained from Agro-lambacin super 315 EC (5.07), Pritacet10 EC (4.57) and Modan5%EC (4.46) while the lowest was in Selecron720EC (0.04) and Chloropyriphos48% EC (0.15). Therefore, based on the benefit cost ratio (BCR) and their efficacy insecticides such as Agro-lambacin super 315 EC and Modan5%EC are help full to reduce sesame webworm damage in the study area and other similar agro ecologies.

Key words: Incidence, Sesame webworm, Sesame, Infestation, Injury, Management

Introduction

Sesame (*Sesamumindicum L.*) is an annual plant that belongs to the family *Pedaliaceae*. It is one of the world's oldest oil seed crop grown mainly for its high oil content of the seeds that contain 52 to 57% oil and 25% protein content (Khan 2009). India, China, Myanmar, Sudan, Uganda and Ethiopia are the important Sesame producing countries in the world and India ranks first, both in cultivated area and production of this crop in the world (Egonyu et al. 2005). Ethiopia ranks among the top five world producers of sesame seed (Singh, 1983). But according to (Michael

2016) Ethiopia is the fourth largest producer of sesame seed in the world behind India, China and Sudan. In Ethiopia, sesame seed production is the leading oil crop and more than four million smallholder farmers are relying on the sesame production for their livelihood (Dennis 2014). Tigray (36%), Oromia (17%) BenishangulGumuz (15%), Amara (31%) regions are the major producers in Ethiopia (Adefris 2011). Within Tigray the Western zone is the main production area with many large commercial and small scale farmers (about 90,000 producers) and it is a good source of income in these areas.The causes for low-level productivity of the crop are many and diverse, among these, insect pest is one of the most important factors affecting production of sesame both in quality and quantity.

Insect pests such as Sesame webworm *(Antigastra catalaunalis)*, sesame seed bug (*Elasmolomus sordidus*), gall midge (*Asphondil iasesami*), and Indian meal moth (*Plodiainter punctella*) are the major insects of sesame during its different growing stages and postharvest. Sesame webworm (*Antigastra catalaunalis)* is the most serious pest of sesame which accounts for approximately 90 % of the yield losses (Egonyu et al. 2005); however losses in yield are much variable depending upon the pest reaction of different varieties and season (Ahirwaret al. 2010). Incidence of sesame webworm in western Tigray was 66% ± 27.8 (Zenawi et al. 2016a). Before 4 years ago Dimethoate was recommended by Humera Agricultural Research Center for the control of sesame webworm but now a day this insecticide is not effective in controlling sesame web worm and searching another optional insecticide is critically important to figure out the problem Objectives;To evaluate the efficacy of different insecticides against sesame webworm (*Antigastra catalaunalis)*in Western Tigray

Materials and Methods

Description of study areas

The field experiment was conducted at Humera Agricultural Research Center at three locations (Humera, Banat and Maygeba) during the main growing season in 2017 and 2018. Humera is located at an altitude of 604 m.a.s.l, 14°06′N latitude and 38°31′E longitude. The dominant soil type of Humera area is chronic vertisol black in color. The agro ecology of the region is hot to warm semiarid plain sub agro ecology. The mean annual temperature is 27.6^{0}C.The annual rainfall ranges from 400-650 mm which lasts from June to September. Banat is located at geographic coordinate 13°78′04″ N latitude and 36°39′77″ E longitude and at an altitude of 593 m.a.s.l. The dominant soil type of this area is chromic vertisol black in color. The mean annual temperature is 28^0C. While the third location Maygaba is located in 13°98′ N latitude and 37°68′ E longitude at an altitude of 896m.a.s.l.Nine insecticides (Diaznon60%EC, Dimethoate40%EC, Selecron720EC,Modan5% EC (lamdacylothrin), Carbaryl85% WP, Agro-lambacin super 315 EC, Chloropyriphos48% EC, Con-Fidence350SC, Pritacet10% EC) and one control were used as experimental materials to conduct the experiment.

The newly released sesame variety Setit-2 was used as a planting material to evaluate the efficacy of nine insecticides and one control on controlling sesame webworm. The experiment was laid down in randomized complete block design (RCBD) with three replications. Individual plots had a size of 5 meters row length and 2 meters width with inter and intra row spacing of 40 cm and 10 cm respectively. The path between blocks and plots were maintained 2.5 m and 2 m respectively.The insecticides were sprayed on the plots with the help of hand operated knapsack sprayer based on their recommended rate of Diazinon60 EC=2lt/ha, Agro-lambacin super 315 EC=400ml/ha, Carbaryl85% WP=2kg/ha, Chloropyriphos48% EC =2lt/ha, Con-Fidence350SC=500ml/ha, Dimethoate40%EC =2lt/ha Modan5%EC=1lt/ha, Pritacet10 EC=250ml/ha, Selecron720EC =1lt/ha at 2 and 4 weeks after crop emergence (WAE).

Data collection

All the necessary data; incidence, leaf, flower and capsule injuries, number of capsule per plant and yield kg ha^{-1} were recorded from the randomly selected and tagged five plants and finally mean of the five plants were taken for each parameters. Yield data was taken from the three central rows of the plot and converted in to hectares.

- **Incidence**: was estimated by counting infested plants within the plot divided to the total plants in the plot multiplied by 100.
- **Severities**:
  - Leaf injury
    Percent leaf damage = (Number of damaged leaves)/ (Total Number of leaves) X100
  - Flower injury

Percent Flower injury = (Number of injured flowers)/ (Total Number of flowers) X100

- Pod (capsule) injury

  Percent pod (capsule) injury = (Number of injured pods (capsules))/ (Total Number of pods (capsules)) X100

The percent losses or percentage of increased in yield of treated plots over the control (untreated) plots was calculated on the basis of formula (Khosla, 1977) as given below:

Percent increase in yield = (X1-X2)/X1 x100%

Where, X1 is the mean yield in treated plots

X2 is the mean yield in untreated plots

Gross income was calculated by multiplying of the yield difference (kg/ha) between the mean yield in chemical treated plots and control (untreated) plots of all treatments with the actual price of sesame per kilogram. Management cost (cost of chemical and spray only) was calculated but the other production costs were considered as similar for all the treated and untreated plots. Then net income was also calculated by subtracting of the management cost from the gross income. Finally, the economic analysis of yield data of all the treatments and cost benefit ratio (C: B) was calculated with the following formula used by (Biswas 2006).

Cost Benefit Ratio=(Net income)/ (Management cost)

The cost benefit analysis was calculated using partial budget method (CIMMYT 1988) by including costs of labor, insecticide and spray equipment were taken based on the price in the locality. The costs and benefit ratio were calculated per hectare basis and ten percent of the yield was deducted from the total grain yield, since farmers in the area were assumed to obtain 90% of experimental yield

Data analysis

Data was analysed using computer statistical software SAS software 9.1 version and means comparison were made using Tukey'stest at 5% probability level.

Results and Discussion

Result of the combined analysis of variance revealed that the chemical insecticides showed a significant difference on incidence of sesame webworm, leaf injury, flower injury, capsule injury, number of capsules per plant and grain yield (Table 2). The highest incidence of sesame webworm was recorded on the control (58.72%) plots followed by Chloropyriphos 48%EC (49.51%) while the remaining all chemical insecticides were recorded the lowest infestation which were significantly different as compared with the chemical untreated (control) plots. The highest Leaf and flower percentage injury due to sesame webworm was also scored at the chemical untreated (Control) plots as compared with the chemical treated plots. Similarly capsule injury percentage was high at the chemical untreated plots followed by Diazinon60% EC (9.89%) and Con-Fidence350SC (8.70 %) while the lowest was recorded by Dimethoate40%EC (5.16%) but not significantly different from Carbaryl85% WP (7.61 %), Chloropyriphos48% EC (7.19%), Modan5%EC(6.2 %), Pritacet10 EC(6.02) and Selecron720EC (6.01). Infestation and severity of sesame webworm was highly reduced by the chemical insecticides. This result is in line with (Zerabruk 2018) who reported that infestation of sesame webworm (leaves, flowers and capsules injury) was effectively controlled in all sesame varieties with three foliar sprays of Diazinon 60% EC at the rate of 1 litter/ha.

Severe infestation of sesame webworm, leaf, flower and capsule injury percentage on sesame can affect yield considerably.10 to 71% plant infestation and 10 to 43.5% capsule infestation, resulting in 8.9 to 71.5% yield loss (Singh, 1983). Infestation of sesame webworm was greater than 80% and 50% of the capsules were seriously affected and resulted 50% yield losses (Simoglou et al. 2017).

The highest number of capsules per plantwas recorded from the plots sprayed with insecticide Diaznon60%EC (32.35), Agro-lambacin supper315EC (31.81) and Modan5%EC (29.30) which are statically pair with Carbaryl85% WP (28.47), Chloropyriphos48%EC (27.07), Dimethoate 40%EC (27.17), Pritacet10 EC(27.68) and Selecron720EC (28.04) while the lowest was recorded in plots sprayed with the insecticide confidence (23.89) and control (20.13) plot (Table 1). Similarly the highest grain yield was recorded from the plots sprayed with Agro-lambacin supper315EC (417.15 kg/ha), Diaznon 60%EC(413.02kg/ha), Dimethoate40%EC (407.99kg/ha), Pritacet10 EC (406.05kg/ha), Carbaryl85% WP (403.16kg/ha), and Modan5%EC (400.27kg/ha) which are significantly different from the control but statically similar with Chloropyriphos48% EC (363.81 kg/ha), con-Fidence350SC(370.17 kg/ha) and Selecron720EC (320.64 kg/ha) while the lowest grain yield was recoded from the control or untreated (282.26 kg/ha) plots. This result indicated that protection of sesame webworm with chemical insecticides reduced the grain yield losses of sesame. This is in line with (Mamta 2017) who reported that maximum grain yield was recorded on insecticide treated sesame byspinosad (8.22 q ha-1) followed by indoxacarb (8.18 q ha-1), acephate (7.85 q ha-1) and carbaryl (7.59) and these chemicals were best in enhancing the yield of sesame. Similarly (Zerabruk 2018) reported that the grain yield of all the tested varieties was significantly higher in the plots treated with Diazinon60% EC. Controlling of *A. catalaunalis* with two applications of dimethoate40% applied at a rate of 2 l/ha at 2 and 4 weeks after sesame germination was effective (Zenawi et al. 2016b). Effective control and increased yield were reported with the use of endosulfan (Ghorpade and Thakur 1995).

Table 1. Yield of sesame and sesame webworm damage as affected by different insecticides based on the pooled data in 2017 and 2018, Western Tigray, Ethiopia

Treatment name	Inci (%)	LI (%)	FI (%)	CI (%)	NCPP	Yield (kg/ha)
Agro-lambacin super 315 EC	45.18^{bc}	16.47^{b}	29.9^{b}	8.83^{abc}	31.81^{a}	417.15^{a}
Carbaryl85% WP	43.34^{bc}	20.66^{b}	32.61^{b}	7.61^{bcd}	28.47^{ab}	403.16^{a}
Chloropyriphos48% EC	49.51^{ab}	19.19^{b}	32.35^{b}	7.19^{bcd}	27.07^{ab}	363.81^{ab}
Con-Fidence350SC	45.22^{bc}	19.54^{b}	35.57^{ab}	8.70^{abc}	23.89^{bc}	370.17^{ab}
Control	58.72^{a}	31.15^{a}	43.31^{a}	11.12^{a}	20.13^{c}	282.26^{b}
Diazinon60% EC	37.70^{bc}	19.39^{b}	28.67^{b}	9.89^{ab}	32.35^{a}	413.02^{a}
Dimethoate40%EC	42.83^{bc}	19.56^{b}	35.40^{ab}	5.16^{d}	27.17^{ab}	407.99^{a}
Modan5%EC	45.37^{bc}	15.49^{b}	26.65^{b}	6.2^{cd}	29.30^{a}	400.27^{a}
Pritacet10 EC	45.37^{bc}	21.18^{b}	31.41^{b}	6.02^{cd}	27.68^{ab}	406.05^{a}
Selecron720EC	36.2^{c}	19.48^{b}	32.67^{b}	6.01^{cd}	28.04^{ab}	320.64^{ab}
L.S.D(±)	12.77	7.14	9.74	3.24	5.28	107.59
Grand mean	44.48	20.21	32.86	7.67	27.60	375.45
CV (%)	35.39	43.56	36.57	52.16	23.61	35.32
Insecticide	*	**	*	**	***	*
Location	***	ns	ns	ns	****	***
Year	***	ns	***	***	ns	***
Insecticide*location	ns	ns	ns	ns	ns	ns
Insecticide*year	ns	ns	ns	ns	ns	ns

Means followed by the same letter(s) with in a column are not significantly different at 5% level of significance, NCPP =number of capsule per plant, Inci =Incidence, LI=Leaf injury, FD=flower injury, CD= capsule injury, LSD= List significance difference, CV (%) = Coefficient of variance, ns= Not significant

Economics and grain yield losses

The average yield, yield loss of sesame caused by sesame webworm and the economics of different insecticides of pooled data of 2017 and 2018 are presented in (Table 2). The highest seed yield 375.44, 371.72, 367.19, 365.45, 363.24 and 362.82 kg/ha was obtained from the plots which received two sprays of Agro-lambacin super 315 EC, Diazinon60%EC, Dimethoate40%EC, Pritacet10 EC, Modan5%EC and Carbaryl85% WP respectively. But these were statistically similar to those plots which receivedChloropyriphos48% EC, Con-Fidence350SC and Selecron720EC.This result is in line with (Patil et al., 1992) who estimated that the yield losses of sesame caused by major insect pests was 36.56% when Carbaryl 0.2% sprays at 35 and 50 days after crop emergence. The highest avoidable yield losses due to sesame webwormin different insecticides were recorded on Agro-lambacin super 315 EC (32.33%), Diazinon60% EC(31.66%) and Dimethoate40%EC(30.82%) respectively while the lowest was recorded on Selecron720EC (12.0%), Chloropyriphos 48% EC (22.42%), and Con-Fidence350SC (23.75%). Different levels of yield losses on sesame by sesame webworm were reported from different reports (Nayak et al., 2015) 18.3 to 22.9% and (Bharodia et al., 2007) 57.60 %.The highest BCR was obtained from Agro-lambacin super 315 EC(5.07), Pritacet10 EC(4.57) and Modan5%EC(4.46) while the lowest was inSelecron720EC (0.04) and Chloropyriphos48%EC (0.15).

Table 2. Mean farmers adjusted grain yield, yield loss of sesame caused by Sesame webworm, net profit and C: B ratio of different insecticides of pooled 2017 and 2018, in Western Tigray, Ethiopia.

Treatment name	Seed yield(kg/ha)	Increased yield over control (kg/ha)	Per cent loss in yield	Cost of insecticide and spray (birr/ha)	Gross income(birr/ha)	Net income (birr/ha)	Benefit cost ratio (BCR)
Agro-lambacin super 315 EC	375.44	121.41	32.33	1000	6070.50	5070.5	5.07
Carbaryl85% WP	362.84	108.81	30.0	1400	5440.50	4040.50	2.88
Chloropyriphos48% EC	327.43	73.4	22.42	3200	3670	470	0.15
Con-Fidence350SC	333.15	79.12	23.75	1000	3956	2956	2.95
Control	254.03	0	0	0	-	-	-
Diazinon60% EC	371.72	117.69	31.66	1400	5884.5	4484.5	3.20
Dimethoate40%EC	367.19	113.16	30.82	1400	5658	4258	3.04
Modan5%EC	363.24	109.21	30.07	1000	5460.50	4460.5	4.46
Pritacet10 EC	365.45	111.42	30.49	1000	5571	4571	4.57
Selecron720EC	288.58	34.55	12.00	1800	1727.50	-72.5	-0.04
Means	342.14	88.10					

Note: Mean farmers adjusted yield (harvested grain yield kg/ha * 10%), Price of sesame seed=50 birr/1kg, Cost of labor=100 birr/day/labor, Cost of insecticides (Diazinon60%EC=300, Agro-lambacin super 315 EC=800, Carbaryl85% WP=400, Chloropyriphos48% EC=800, Con-Fidence350SC=800, Dimethoate40%EC =300,Modan5%EC=400, Pritacet10 EC=800, Selecron720EC =800 birr/litter) , amount of insecticide (Diazinon60 EC=4lt ,Agro-lambacin super 315 EC=800ml, Carbaryl85% WP=4kg, Chloropyriphos48% EC=4lt, Con-Fidence350SC=1lt, Dimethoate40%EC =4ltModan5%EC=2lt, Pritacet10 EC=500ml, Selecron720EC =2lt) being required for 1 hectare to a double spray , Total of 2 labors for each insecticide , were used, Other variable costs were the same for all the treatments, BCR = Net income/Management cost

Conclusion and Recommendation

The present study revealed that sesame webworm damaged the sesame crop seriously at flowering and pod setting stages. Spraying of different chemical insecticides reduced the incidence, leaf injury, flower injury and capsule injury by sesame webworm and increases the grain yield as compared with the control. The highest avoidable yield losses were obtained from Agro-lambacin super315EC, Diazinon60%EC, Dimethoate40%EC, Pritacet10EC and Modan5%EC. Similarly, the highest BCR was also recorded from Agro-lambacin super 315 EC, Pritacet10 EC and Modan5%EC. So, based on the benefit cost ratio (BCR) the recently introduced insecticides Agro-lambacin super 315 EC and Modan5%EC could be helpful to the farmers for formulating appropriate management techniques and to reduce sesame webworm infestation.

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1.3. Evaluation of the Efficacy of Pre-emergence Herbicides to Control Grassy and Broad Leaf Weeds of Sesame in Western Tigray

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Abstract

In Ethiopia sesame production and productivity is low. Of the several constraints in sesame production, weed infestation is the major factor that limits the yield of sesame. Although, there are recommended herbicides for sesame but not in our growing condition. Therefore, objectives of this study were to evaluate efficacy of the pre emergence herbicides on sesame weed control and to estimate the optimum application rate of the pre emergence herbicides. Field experiments were conducted in Humera Agricultural Research Center (HuARC) experimental stations in 2017 and 2018 growing season. Treatments were arranged in a factorial RCBD with three replications. The treatments in the herbicides consisted of three pre emergence herbicides (Five star 96/S-metolachlor, Stomp 455 CS, Anchor 360 CS) and four application rates (0.5, 1, 1.5,2 litter/ha).. Application of the herbicides did not show significant difference on phenological and growth parameters of sesame. All rates of five-star, higher dose of anchor and the hand weeding scored lower weed density (<35 weeds/m2) and lower fresh weed biomass. The lower doses of anchor and stomp sprayed plot have scored higher fresh weed biomass. Moderate crop injury was scored on the higher doses of the pre emergence herbicides (anchor @ 2 l/ha, five star @ 2 l/ha and stomp @ 2 l/ha) at early growth stage of the crop. Application of anchor @ 1.5 l/ha and five star @ 1 l/ha has scored higher seed yield in par with the hand weeding. In general, applications of five star @ 1 l/ha and Anchor@ 1.5 l/ha were the best herbicides in controlling sesame weeds and improving the seed yield of sesame.

Key words: Pre emergence, Weed density, Herbicides, crop injury, Seed yield

Introduction

Sesame (*SesamumindicmL.*) belongs to the order Tubiflorae and family Pedaliaceae cultivated for their seed. It is probably the most ancient oilseed known and used by man (Parkes and Weiss, 1983; Weiss 2000). The seeds are rich source of oil, protein, calcium, phosphorus and oxalic acid (Caliskan et al. 2004). Buhler and Oplinger (1990) indicated that part of the attraction for sesame is undoubtedly its high fat (50% oil) and protein content (up to 25% protein by weight). The seed contains 50-60% oil, which has excellent stability due to the presence of natural antioxidants such as sesamolin, sesamin and sesamol (Brar et al. 1979; Caliskan et al. 2004) that provide long shelf life. It is also used in the pharmaceutical industry, in the manufacture of margarine and soap, as a fixative in the perfume industry, in cosmetics and as synergist for insecticides (Salunkhe and Desai 1986). In Ethiopia particularly in Western Tigray, sesame is used as cash crop, export commodity, raw materials for industries and as source of employment opportunity (Personal observation). A sizable proportion of the population, therefore, generates income from oilseed farming, trade and processing (Alemayehu and Alemaw 1997).

In Ethiopia, sesame grows very well in the lowlands. Within the lowlands, KaftaHumera is the major sesame producing area of Ethiopia (Zewdie et al. 1992). Area allocated to sesame both at regional and national level increases from time to time. In Ethiopia and in particular in Kafta Humera wereda, the yield of sesame is very low much more below the national average (700 kg/ha). The average yield of sesame in Kafta Humera wereda/westyern zone of Tigray is about 400 kg/ha to 500 kg/ha (Personal observation). There are numbers of constraints that limit the production of sesame, like pest infestations (weeds, insects and disease), water logging (poor drainage), lack of optimum plant population, seasonal delay, low yielding cultivars, post-harvest loss, poor storage facility, difference in capsule maturity, shattering etc. Out of the several constraints in sesame production, weed infestation is one of the major factor limiting the yield of sesame as its seedling growth is slow during the first four weeks makes it a poor competitor at earlier stages of crop growth (Ijlal et al. 2011). The early growth period is the most critical stage at which stress of any kind can affect the economic yields.

The sesame growing areas of the western Tigray are highly infested by different broad-leaved and grass weeds. A weed survey conducted by Humera Agricultural Research Center/un-published data) revealed that more than 80 weed species were recorded and identified as weed pests for sesame and of the weed weeds, *Commelina foecunda* was the most dominant, abundant, and frequently occurred weed. Sesame is very sensitive to weeds from emergence up to 4 WAE/ which can cause >80% yield loss (Amare, 2011). Insufficient weed control during early growth period of sesame may cause yield reduction between 35 to 70% (Tyagi et al. 2013). Moreover, (Upadhyay 1985) have stressed that early growth of sesame is slow, so making suppression of weed growth at crop establishing is important. Although, there are recommended herbicides for sesame but not in our growing condition. Weeds are harrowed by manpower/labor using simple tool called Mewled yet. In the same study area, pendimethalin @ 2 l/ha, quizalofop @ 2 l/ha and sharoxy @ 1.5 l/ha produced good economic yield, low crop injuries and efficient weed control in Mung bean (Zenawi 2020). Sujithra et al. (2018) stated that the weed free check and application of alachlor @ 1.5 kg/ha(pre emergence) + quizalofop ethyl @ 50 g/ha (post on 25 DAS) recorded highest seed yield of sesame. The pre application of acetochlo, pethoxamid, and S-metolachlor (five star) at the 1x dose resulted in no injury (little sesame injury) 2 weeks after treatment, whereas 15 to 30% injury was observed with these herbicides applied at the 2x dose (Grichar et al. 2018). But labor availability is becoming a notorious issue while the production area is still increasing (Kafta Humera woreda office of agriculture, un-published data). Furthermore, office of Labor and Social Affairs of Kafta Humera Woreda (un-published data) reported that labor availability is decreasing from time to time and the labor cost is increasing from year to year dramatically. This trend is putting financial pressure on investors and smallholder farmers. Therefore, there is a need to use herbicides when labor is in shortage for hand weeding. Hence, this study was intended to evaluate efficacy of the pre emergency herbicides and determine optimum application rate.

Materials and Methods

Field experiments were carried out in two locations of Humera Agricultural Research Center (HuARC) experimental stations namely HuARC station and Banat station (Figure 1) during 2017 and 2018 cropping seasons. Agro-ecologies of the locations are generally, described as hot to warm semiarid plain having Vertisol soil type. HuARC station is characterized by mean temperature of about 30°c, annual mean rainfall of 450 mm, altitude of 600 m.a.s.l and 80 days length of growing season; while Banat station is characterized by mean annual rainfall of 650 mm, mean monthly temperature of 27-29^{o}c, altitude of 635 m, and 90 days length of growing season.

The experiments were laid out in factorial RCBD having three replications. The path between blocks and plots were (2 m and 1m, respectively) and each plot had 5 m length and five rows. The treatments in the herbicides consisted of three pre emergence herbicides (Five star 96/S-metolachlor, Stomp 455 CS, Anchor 360 CS) and four application rates (0.5, 1, 1.5,2 litter/ha).A Weedy check and hand weeding (3 times) was used as standard checks. Generally, the experiment consisted of 14 treatments. *Setit-2* sesame variety was used as a test variety and 100 kg NPS/ha, 50 kg urea/ha and all managements practices were applied to all experimental units in both locations uniformly. The field was ploughed and harrowed in both seasons and locations to obtain a fine tilt, there after marked into plots. Herbicides were applied soon after planting before sesame seeds were emerged. Hand knapsack sprayer fitted with flat fan nozzle was used and 1000 L/ha of water was used to spray the herbicides. Seeds were planted as deep as 3-4 cm. All field management practices were performed properly as per the recommendations to the study areas.

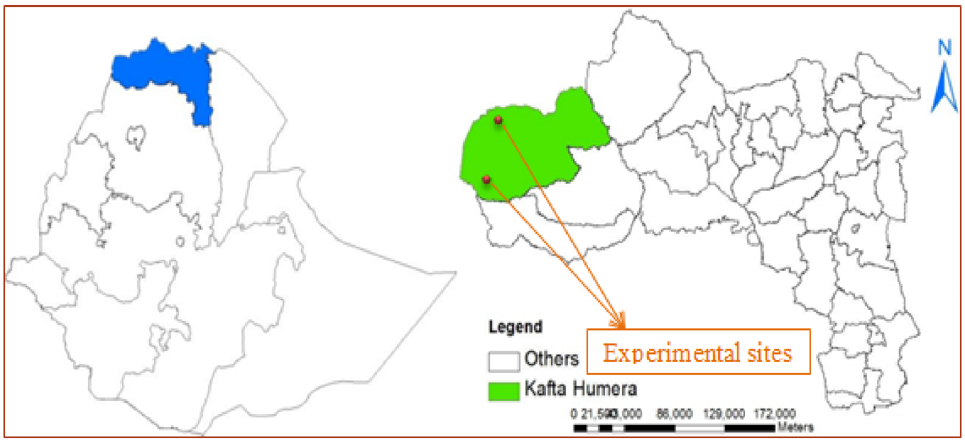

Figure 1. Map of the experimental sites (Zenawi et al 2019)

Data such as stand count @ 13, 27 DAE & harvest, number of branches per plant, stand count per meter square, plant height, number of capsules per plant, length of capsule bearing zone per plant, number of seed per capsule and seed yield per hectare (kg/ha) were collected. Weed density and fresh weed biomass were recorded at 14 & 28 DAE with the help of 50 x 50 cm quadrant by throwing it randomly at two places in each plot. Weed frequency and dominance were calculated. Sesame injury (stunting) were estimated at 13 and 27 DAE 0-10 scale according to Rao (2000) (Table 1).

The collected data were subjected to analysis of variance (ANOVA) and mean separated least significant difference (LSD) using Genstat version 18. Price of grain per kg and total sale from one hectare, price of herbicides, total labor costs were recorded.

Table 1. Crop injury level score (Rao 2000)

Score	Effect	Crop discretion
0	None	No injury
1		Slight stunting, discoloration
2	Slight	Some stand loss, discoloration
3		Pronounced injury, but not persistent
4		Moderate injury, recovery possible
5	Moderate	More injury, recovery doubt full
6		Near severe injury
7	Severe	severe injury, stand loss
8		Destroying, few plant survived
9	Complete	Very Few plant survived
10		Completed destruction

Results and Discussion

Weed abundance and dominance

Commelina foecunda (Maimaio), *Corchorus fascicularis* L. (Hamirai), *Dinebraretro flexa* (Chwchwit), *Lactucaserriola* (Demaito), S*orghum halepense* (Adar), *Rahynochosiamalacophylla* (Teken), *Ipomoea spp* (Hareg) were recorded as major weeds in the area (Fig1). A study conducted in Iran revealed that *Echinochloa crus-galli*, *Chenopodium album* and *Amaranthusretro flexus* were main weeds which competed successfully with sesame (Vafaei et al. 2013). A weed survey conducted by Humera Agricultural Research Center(HuARC (2017) un-published data) revealed that more than 80 weed species were recorded and identified as weed pests for sesame. When the abundance and dominance for the weeds grown in the experimental area were calculated, *Commelina foecunda* (maimaio) scored the higher values (55 and 66%) for both abundance and dominance respectively, while all the remaining weeds scored low abundance and dominance (Fig. 1). A survey conducted in sesame farms of western Tigray showed that about 91.7% infestations with *C. foecunda* (Zenawi et al. 2018). The same authors found that 53.7 and 859 weeds/m^2 of *C. foecunda* abundance and density, respectively. Application of Alachlor @ 1.5 kg/ha as pre emergence + Quizalof ethyl @ 50 g/ha on 25 DAS as early post emergence recorded a lesser weed density (Sujithra et al. 2018).

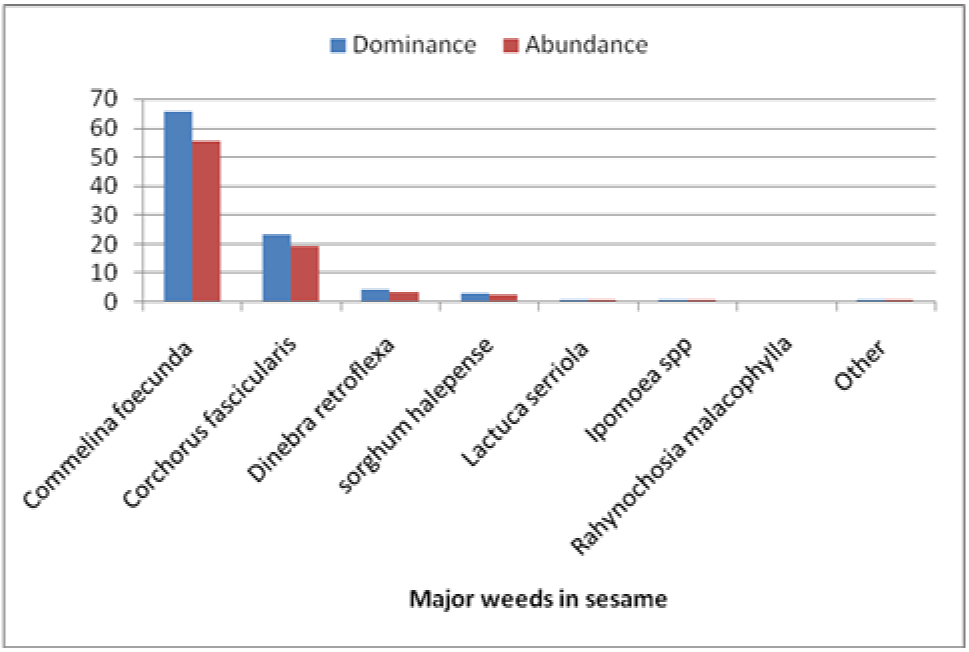

Figure 2. Weed dominance as affected by the pre-emergence herbicides

Efficacy of the herbicides to control weeds on sesame

There was statistically significant difference among the different herbicides and their application rates in fresh weed biomass in all locations and years (P=0.05). The fresh weed biomass in Humera testing site was statistically similar among treatments. In Banat, five star and anchor sprayed plots scored lower fresh weed biomass, which were statistically similar with the hand weeding. In the other way, the higher fresh weed biomass was recorded in the stomp sprayed plots and the weedy check. At the early growth stage the crop, five star was incredibly effective in controlling the weeds in 2017 (Fig.3). And in the vegetative growth stage of the plant, both five star and anchor sprayed plots were clean of weeds like the hand weeding, while stomp sprayed plot was as the same as the weedy check (Fig.4). Generally, we can conclude that application of five star and anchor are efficient enough to control weeds in sesame. Application of pre-emergence herbicides, pendimethalin 750 g/ha recorded the highest seedling vigour index followed in sesame on sandy loam soils (Babu et al. 2016). Moreover, application of both pre-emergence herbicides alachlor and trifluralin increased rootlet, shoot let, and seedling weights (Vafaei et al. 2013). The lowest weed density (12/m2) was observed under the weed-free check, followed by quizalofop 40 g/ha as post-emergence and pendimethalin 450 g/ha as pre-emergence and the highest weed density (163/m2) was recorded under the weedy check (Sagarka et al. 2013).

Figure 3. Response of sesame (2 weeks after emergence) to application of pre emergence herbicides Five star (A), Anchor (B), stomp (C) and control (D)

Higher seed yield was recorded from the hand weeding and achor sprayed plots in both locations during 2017, while the weedy check and stomp sprayed plots scored lower seed yield. In 2018 production year, higher seed yield was harvested from five star sprayed plot and the lower from the weedy check (Table 2).Some researchers have shown that sesame yield was increased by the application of metolachlor and trifluralin (Vafaei et al. 2013) and was not affected by S-metolachlor (Grichar et al. 2001). Highest seed yield was recorded in pre-emergence application of herbicide with one hand weeding at 30 DAS and weedy check recorded lower seed (Mane et al. 2017).

Figure 4. Response of sesame (6 weeks after emergence) to application of pre emergence herbicides Five star (A), Anchor (B), stomp (C) and control (D)

Table 2. Treatment effect on sesame yield and weed biomass in 2017 and 2018 in W/ Tigray

Pre emergence Herbicides	Humera 2017		Banat 2017		Banat 2018	
	FWB/ m^2	Seed Yield kg/ha	FWB/ m^2	Seed Yield kg/ha	FWB/ m^2	Seed Yield kg/ha
Anchor 360 CS	53	675	316	466	472	464
Five star 96/ S-metolachlor	56	495	128	367	406	541
Stomp 455 CS	45	554	671	275	1006	330
Hand weeding(3 times)	21	904	11	601	0	498.7
Weedy check	33	561	727	232	628	214
CV (%)	109	39	41	39	78	35
LSD (P=5%)	NS	393	255	245	759	256

FWB=fresh weed biomass

Interaction effect treatments on weed infestations and plant performances

There was significant difference in weed density, fresh weed biomass and seed yield among the interaction of herbicides and their application rates (P=0.05). The lower weed density (22-35 weeds/m^2) were recorded from the application of five star @ 1-2 l/ha and the hand weeding, while maximum weed density (>130 weeds/m^2) were recorded in the weedy check and stomp sprayed plots (Table 3). Application of anchor @ 2 l/ha and five star @ 1.5-2 l/ha scored lower fresh weed biomass, which were significantly similar with the hand weeding. In the other side, stomp (@ 0.5-2 l/ha) and the weedy check scored maximum fresh weed biomass per meter square (Table 3). Mane et al. (2017) reported that the weed free check, Pendimethalin (PE) @ 0.75 kg a.i. ha^{-1} + one hand weeding at 30 DAS and Quizalfop-ethyl (POE) 0.05 kg a.i. ha^{-1} + one hand weeding at 45 DAS recorded minimum weed growth and maximum weed control efficiency. pre-plant incorporation (PPI) of fluchloralin at 1.0 kg/ha + hand weeding on 30 DAS 0N3 registered significantly lowest total weed density (Svathi et al. 2005).

Plant height was statistically insignificant among the treatments whereas seed yield was highly significant (P=0.05). The maximum seed yield (>600 kg/ha) was scored from anchor @ 1.5 l/ha, five star @ 1 l/ha and hand weeding. In contrast the lower seed yield (300-400 kg/ha) was recorded on the weedy check, stomp (all rates) and five star @ 0.5 l/ha (Table 3). Sujithra et al. (2018) stated that the weed free check and application of alachlor @ 1.5 kg a.i. ha^{-1}(pre emergence) + Quizalofop ethyl @ 50 g a.i. ha-1 (post on 25 DAS) recorded highest seed yield of 559 kg/ha and 550kg/ha respectively. Application of fluchloralin 1.0 kg/ha as pre plant along with hand weeding at 30 DAS recorded significantly the highest seed yield of 758 and 745 kg/ha during 2002 and 2003, respectively followed by alachlor 1.25 kg/ha as pre emergence along with hand weeding on 30 DAS (Svathi et al. 2005).

In general, applications of five star @ 1 l/ha and Anchor@ 1.5 l/ha were the best herbicides in controlling sesame weeds and improving the seed yield of sesame. Although stunting was noted with higher herbicide rates, the treated and untreated plants started to flower at approximately the same time and produced a similar yield (Grichar et al. 2012).

Table 3. Combined Sesame yield, weed density and weed biomass as affected by the pre-emergence herbicides during 2017 and 2018 in Western Tigray, Ethiopia.

Pre emergence Herbicides	Application rate l/ha	Ph (cm)	Weed density/m^2	Fresh weed biomass/m^2	Seed Yield kg/ha
Anchor 360 CS	0.5	117.7	120.6^{bc}	238^{abc}	437.2^{a-d}
	1	121	209.7^{d}	368^{bc}	480.6^{a-d}
	1.5	126.3	127.8^{bc}	176.1^{abc}	627.3^{d}
	2	119.4	80.1^{ab}	93.6^{ab}	599.1^{cd}
Five star 96/ S-metolachlor	0.5	113.2	82.2^{ab}	227.3^{abc}	340.1^{a}
	1	126.3	35.2^{a}	170.2^{abc}	613.3^{d}
	1.5	120.8	33.5^{a}	131.9^{ab}	555.9^{bcd}
	2	120.4	22.6^{a}	135.1^{ab}	455.7^{a-d}
Stomp 455 CS	0.5	119.4	131.8^{bc}	761^{d}	407.5^{abc}
	1	115.3	123.6^{bc}	333.9^{bc}	388.7^{ab}
	1.5	123.8	135.3^{bc}	427.2^{c}	377.8^{ab}
	2	115.2	108.2^{b}	296.8^{bc}	346.2^{a}
Hand weeding(3 times)		120.3	35.5^{a}	5.4^{a}	621.8^{d}
Weedy control		114.9	186.4^{cd}	336^{bc}	307.5^{a}
CV (%)		10.2	65.3	98.3	39.7
LSD (p=5%)		11.43	62.67	243.7	309.22
Herbicide		Ns	**	**	**
Application Rate		Ns	Ns	*	ns
Envi		**	**	**	**
Herbi*rate		Ns	**	*	*
Herbi*rate*Envi		Ns	*	**	ns

CV= Coefficient, LSD=Least significant difference

Crop injuries

The analysis of variance showed that significant difference on both crop injuries at 13 and 27 days after emergence (P=0.05). Moderate injury (4) was scored on the higher doses of the pre emergence herbicides (anchor @ 2 l/ha, five star @ 2 l/ha and stomp @ 2 l/ha) at 13 DAE, while others scored lower level of crop injury or some stand loss and discolorations. A moderate injury was scored on stomp @ 2 l/ha at 27 DAE; while five star @ 0.5-1.5 l/ha and anchor @ 0.5-1.5 l/ha were significantly similar with the hand weeding plots. Five star and anchor pre emergences herbicides showed less injury and fast recovery compared to stomp (pre emergences herbicide) (Table 4). Therefore, application of stomp at higher dose has higher crop damage. Pre-emergence application of oxadiargyl 75 g/ha showed phytotoxicity rating of "6" in sesame (Babu et al., 2016). S-metolachlor at the 2 X rate (higher dose) resulted in stunting that ranged from 18 to 27%, while no stunting was noted with the 1/2X rate (lower rate) of herbicide(1/2X) (Grichar et al. 2012). The PRE application of acetochlor, pethoxamid, and S-metolachlor (five star) at the 1x dose resulted in 10% sesame injury 2 weeks after treatment (WAT), whereas 15 to 30% injury was observed with these herbicides applied at the 2x dose (Grichar et al. 2018). Similarly, Sperry (2016) reported that PRE application of S-metolachlor at 1.42-2.78 kg/ha resulted in 41-65% reduction in sesame plant height at 2 WAT, whereas at 4 WAT no injury was observed with the PRE applications of S-metolachlor.

Table 4. Sesame injury score as affected by the pre-emergence herbicides during 2017 and 2018 in Western Tigray, Ethiopia

Pre emergence Herbicides	Application rate l/ha	sesame injury @13 DAE	sesame injury @27 DAE
Anchor 360 CS	0.5	2.1	1.0
	1	2.7	1.4
	1.5	2.7	1.2
	2	4.8	2.8
Five star 96/S-metolachlor	0.5	1.0	1.0
	1	1.4	0.8
	1.5	2.9	2.1
	2	4.0	2.6
Stomp 455 CS	0.5	1.5	2.0
	1	2.1	1.5
	1.5	2.6	2.2
	2	3.8	3.6
Hand weeding(3 times)		0.0	0.0
Weedy check		0.6	1.9
CV (%)		70.9	67.5
LSD (p=5%)		1.6	1.27

Conclusion and Recommendation

Commelina foecunda (Maimaio), *Corchorus fascicularis* L. (Hamirai) were the most dominant (>88) weeds in the study area. Application of the herbicides did not show significant difference on phenological and growth parameters of sesame. All five star sprayed plots and the hand weeding scored lower weed density (<35 weeds/m2), where the lower dose of anchor and all rates of stomp has scored higher weeds/m^2.All application rates of five star and the higher doses of anchor scored lower fresh weed biomass, statistically similar with the hand weeding. The lower doses of anchor and stomp sprayed plot have scored higher fresh weed biomass. In the case of seed yield; application of anchor @ 1.5 l/ha and five star @ 1 l/ha has scored as high as the hand weeding. The weedy check and five star @0.5 l/ha were scored lower seed yield, statistically similar with the stomp sprayed plots. Application of higher dose of the herbicides (2 l/ha) caused some damaging effect on the plant, particularly at young stage of the plant (discoloration, stunted growth, stand loss…).In general, applications of five star @ 1 l/ha and Anchor@ 1.5 l/ha were the best herbicides in controlling sesame weeds and improving the seed yield of sesame. Therefore, according to the results five star @ 1 l/ha and anchor @1.5 l/ha should be recommended to control weeds in sesame as an option to the hand weeding.

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1.4. On Farm Evaluation of Insecticides and Applications Methods for Controlling Sesame Seed Bugs (Elasmolomus sordidus F.) In Western Tigray

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Abstract

Elasmolomus sordidus is currently considered as major post harvest pest which threaten sesame production both during drying in the field and storage. This research was aimed to identifying appropriate insecticide and its application method to control sesame seed bug during “Hila” drying. The experiment was carried out in 2018 after the growing season with split plot design replicated three times. The tested treatments were four chemical (Deltamethrin, Malathion 5%, Lipron 50SC, Malathion 50% ES, control unsprayed and check protected) and 2 spraying methods. The analysis of variance revealed that insecticides and application methods showed significant difference on seed bug infestation and yield. The study indicated that field application of Deltamethrin before Hila staking was effective up to 10 days after staking, where some seed bug appearance occurred after ten days later. Application of Lipron before Hila staking was kept seed bug infestation very low up to threshing. Generally, application of Deltamethrin and Lipron before Hila staking was found better in protecting sesame seed bug infestations and minimizing sesame seed losses due the insect. Marginal rate of return revealed that by investing 1 birr produce 3.77birr with spraying of Lipron at base before Hila stacking. Application of Deltamethrin and Lipron at base of stack is helpful to control sesame seed bug.

Keywords: *Elasmolomus sordidus*, Hila, Insecticides application method, *Sesamum indicum*

Introduction

Sesame (*Sesamumindicum*L.) belong to Pedaliaceaefamily (Vittori Gouveia et al. 2016) and one of the oldest oilseed crops (Pham et al. 2010). It is an erect herbaceous annual plant with both single stemmed or branched growth habits. It grows up to 2m height (Pham et al. 2010) and with a large tap root of 90 cm (Ashri and Singh 2007).The origin of sesame crop is known to be Ethiopia (Ram et al. 1990). The major sesame producers are Tanzania, Myanmar, India, China, Nigeria and Sudan (FAOSTAT 2017).

In the world, India ranks first in the production area of sesame seeds and is grown in different seasons covering practically all agro-ecological zones (Ram et al. 1990) and (Hwang 2005). Sesame plays an important role in human nutrition, medicinal, pharmaceutical, industrial and agricultural uses (Gharby et al. 2017).

Sesame seed has many culinary applications in many bakery products and for the oil production (raw or roasted). Sesame seed oil is very rich in poly unsaturated fatty acids used in margarine production and cooking oils. Sesame contains significant amounts of the *lignansse samin* and sesamolin. These compounds have beneficial effects on serum lipid levels and liver function and give sesame seed oil a marked antioxidant activity. The lignans are also responsible for the great stability of sesame seed oil to oxidation (Yalcin and Unal 2011). Though sesame have numerous advantagesits production,drying and storage is affected by biotic and a biotic factor. Among the biotic factors, which affects drying and storage of sesame is *Elasmolomussordidus*. In 2016-productionseason,there were high infestation of sesame seed bugs, which were causing substantial yield losses in western Tigray and farmers were spraying different insecticides at high dosage repeatedly but failed to control the pest(Western Tigray Zonal Office of Agriculture, Personal communications/unpublished).

Farmers at Humera area spray Malathion 50% EC and Ethiosulfan 35% EC one to three times at the base of sesame stalks in stack (Selomun 2011). Earlier studies in the current area indicated that sesame seed bug can cause up to 95% yield loss (Muez et al. 2008). The main possible causes for emergence of the sesame seed bug *Elasmolomu ssordidus* are: the great expansion in the area under sesame, the cultivation of so many sesame varieties, the lack of intensification of rotations, delaying the sesame sowing date and destruction of the natural predators and parasitic fauna through an increased unwise application of insecticides to control pests. Ciper Ruimoo 0.25% DP (Cypermethrin) at the dose of $100g/m^2$ gave excellent control for sesame seed bug on sesame when applied to the sol as dust before stacking. Incidence score (0-4); 0=no incidence 1=scatter appearance (<25 SB/Shawer) 2=few incidence (25-50 SB/Shawer), 3= high incidence (50-100 SB/Shawer) 4=dense appearance (>100 SB/Shawer). (Suliman, 2015). Similarly, neem, birbira and pyrethrum powders have good control of the insect in storage (Selomun 2011). Dusting the base of stack and the soil around them with Ethiolathion 5% Dust, and Carbaryl 85% WP is well practiced in Humera area (Mandefro 2009). However, such activity is not known in the study area. Therefore, the objectives of the study was to identify appropriate insecticide and its application method to control for sesame seed bug during "*Hila*" drying

Materials and Methods

Area description

This experiment was conducted in 2018 after the growing season (after harvesting) at Humera Agricultural Research Center (HuARC), where it is situated between 13°14’ to 14°27′N and 36°27′ to 37°32′E. The dominant soil type of the area is chromic vertisol black in color. The annual rainfall ranges between 400 to 600 mm and most of the rain rains in June up to September (Tedla et al. 2018). The annual mean temperature is 29 °C. It is also characterized by hot temperature, erratic rainfall, vast area of plain low lands suitable for large scale and subsistence agriculture including crops and livestock.

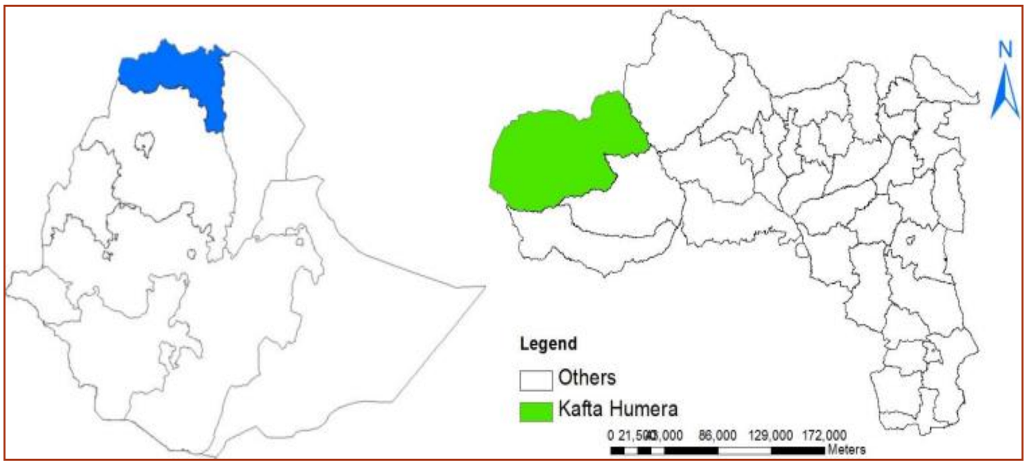

Figure 1. Site map of the study area (Zenawi et al 2018)

The experiment was laid in split plot replicated three times. The treatments were four chemical (Deltamethrin, Malathion 5%, Lipron 50SC and Malathion 50% ES) two checks (unsprayed and protected checks (dried in polyethylenebug) and two spraying methods (spraying the base before staking and spraying the circumference after staking (2m far from the stack)). Insecticides and application methods were placed in whole and sub plot respectively. In each plot there were fifty ties (a Shawer) of sesame stacked and stand together in a Hila form. The experiment was placed in highly infested area that has many sesame residues (Jewjaw) for good source of *Elasmolomu ssordidus* (Fig.2). The insecticides were applied in manufacturer label before Hila stacking at the base and after Hila stacking circumference of the Hila (2 m far from the Hila).

Figure 2. The experimental site with the shawer stacking

Figure 3. Methods of threshing and counting sesame seed bugs

The incidence was checked (0-4 scale) reference every three days for consecutive 14 days in the evening and/or morning (2:00-4:00, 11:00-12:00 morning) since they freely move in those hours.

Incidence scoring was taken in this form; 0=no incidence 1=scatter appearance (<25 SB/Shawer) 2=few incidence (25-50 SB/Shawer), 3= high incidence (50-100 SB/Shawer) 4=dense appearance (>100 SB/Shawer). Data such as number of dead bugs and live seed bugs were counted after threshing (figure 3). Seed yield and yield loss per Shawer were recorded

Number of seeds remaining in a capsule after severe infestation of seed bug was assessed by putting individual capsules tied in a stick in infested area with sesame seed bug (Figure 4.A). Number of healthy seeds (undamaged seeds) from the healthy capsule and from the infested capsule were counted as follow (Figure 4.B,C).

Figure 4. Erect capsules tied in a stick in a severely infested area with sesame seed bugs (A), no. of healthy seeds from protected capsule (B), no. of healthy seeds from infested capsule (C).

Partial budget analysis

The partial budget as described by CIMMYT (1998) was analyzed on seed yield of sesame crop in order to assess the costs and benefits associated with different treatment (insecticides and application methods). Economic analysis was done using the market price for inputs at harvesting and for grain yield at the time the crop was threshing. All costs and benefits were calculated on hectare basis in Ethiopian birr. Seed yield was adjusted down by 10% to minimize the effect of researcher-managed small plots as compared to the farmers managed plots.

The dominance analysis procedure as detailed in CIMMYT (1998) was used to select profitability treatments from the range tested. The marginal rate of return (MMR) is calculated using equation 3 by considering a pair of non-dominated treatments listed in the order of increasing net benefit. MMR denotes areturn per unit of investment in the change of field management tested in the field research.

Gross benefit = economical yield return *price (birr/kg)…………………...……… (Equation 1)

Net profit= gross benefit –total cost that vary……………………………….....…. (Equation 2)

MRR= $\frac{change\ in\ NB}{change\ \ in\ TCV}$…………………………………………………….………..(Equation 3)

Where, MRR= is the marginal rate of return, NB= is net benefit ha^{-1} for each treatment,TCV= is the total variable costs ha^{-1} for each treatment.

Results and Discussion

Sesame seed bug infestation progress after chemical applications

During 3 days after stacking: the analysis of variance revealed that insecticides and spraying methods showed significant difference on sesame seed bug infestation during three days after stacking.

Table 1. Sesame seed bugs infestation trends after insecticide spray in 2011 at Kafta Humera

Treatments,	3DAS	6DAS	9DAS	11DAS	14DAS
Check (protected)	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}
Control (unsprayed)	1.0^{c}	4.0^{d}	4.0^{d}	3.7^{e}	1.3^{bc}
Deltamethrin BS	0.0^{a}	0.0^{a}	0.0^{a}	2.3^{bc}	2.0^{cde}
Deltamethrin CR	0.0^{a}	0.3^{a}	0.3^{a}	3.0^{cde}	2.3^{e}
Malathion 5%D BS	0.67^{b}	2.0^{c}	2.0^{c}	3.7^{e}	1.3^{bcd}
Malathion 5%D CR	1.0^{c}	4.0^{d}	4.0^{d}	3.3^{de}	1.3^{bcd}
Lipron 50 SC BS	0.0^{a}	1.0^{b}	1.0^{b}	0.0^{a}	0.7^{ab}
Lipron 50 SC CR	0.0^{a}	1.3^{b}	1.3^{b}	0.3^{a}	1.0^{b}
Malathion 50% EC BS	0.0^{a}	0.3^{a}	0.3^{a}	2.0^{b}	1.3^{bcd}
Malathion 50% EC CR	0.0^{a}	0.0^{a}	0.0^{a}	2.7^{bcd}	2.3^{e}
CV(%)	68.5	25.6	25.6	24.1	37.8
LSD	0.31	0.6	0.57	0.86	0.88

BS= Spraying at the base of Hila CR= Spraying at the circumstance of Hila, DAS=Days after spray

Scattered level of infestation (1.0) was recorded at control (unsprayed) and Malathion 5%D CR, while the lowest (0.0) was recorded at check (protected) though statically similar with Malathion 50% EC CR, Malathion 50% EC BS, Lipron 50 SC CR, Lipron 50 SC S, Deltamethrin CR and Deltamethrin BS. The insect sesame seed bug is sensitive to any chemical as a result all chemicals spray were effective. This result in line with (Kalaiyarasan and Palanisamy 2005).

During 6 days after stacking: the analysis of variance revealed that insecticides and application methods showed significant difference compared to control (unsprayed). The highest infestation of seed bug (4) was recorded at control (unsprayed), while the lowest infestation (0) was recorded at check (dried in polyethylene bug) though statically similar with Malathion 50% EC CR and Deltamethrin BS. This result in conformity with (Kalaiyarasan and Palanisamy, 2005) in case of Malathion 50%.

During 9 days after stacking: the analysis of variance indicated that insecticides and application methods showed significant difference compared to control (unsprayed) and Malathion 5%D CR. The highest infestation was scored at control (unsprayed), while the (0) was recorded at check (protected) even though statically similar with Deltamethrin BS and Malathion 50% EC CR.

During 11 days after stacking: the analysis of variance revealed that insecticides and application methods showed significant difference compared to control (unsprayed). The highest infestation (3.7) was recorded at control (unsprayed), while the lowest (0) was recorded at check (protected) contrariwise statically similar with Lipron 50 SC BS.

During 14 days after stacking: the analysis of variance revealed that insecticides and application methods showed significant difference among treatments. The highest infestation (2.3) was recorded at Malathion 50% EC CR, while the lowest (1.3) was recorded at control.

Table 2. Seed bug infestations and yield responses as affected by the insecticides and application methods in 2011at Kafta Humera, Ethiopia

Treatment	Incidence (score 0-4)	Dead SB	Live SB	1000 SW (g)	Yield kg/50 ties	Yield loss%
Check protected	0	0.0	0.0	3.1	1.17	0
Control unsprayed	High/3	0.0	190.0	2.1	0.53	40.6
Deltamethrin BS	Scatter/1	2.0	31.3	2.7	0.79	17.9
Deltamethrin CR	Scatter/1	3.3	154.3	2.8	0.71	24.3
Malathion 5% D BS	Few/2	2.3	78.3	2.5	0.51	41.6
Malathion 5% D CR	High/3	4.0	119.0	2.3	0.49	43.6
Lipron 50 SC BS	Scatter/1	11.7	8.7	2.8	0.84	13.7
Lipron 50 SC CR	Scatter/1	8.7	13.7	2.6	0.66	28.8
Malathion 50% EC BS	Scatter/1	6.0	38..7	2.7	0.66	28.5
Malathion 50% EC CR	Few/2	3.0	30.0	2.9	0.63	21.1
CV(%)	37.8	31.7	31.7	6.9	28.2	146.3
LSD	0.88	2.23	36.1	0.31	0.35	121.8

SB=Seed bugs, SW= SW= Seed weight, CV, Coefficient of Variation, LSD= Least significant difference

Incidence

The analysis of variance revealed that insecticides and application methods showed significant difference on incidence among treatments. The highest incidence was scored at control (unsprayed) followed by Malathion 5% D CR, while the lowest was scored at check (protected) though statically similar with Deltamethrin BS, Deltamethrin CR, Lipron 50 SC BS, Lipron 50 SC CR and Malathion 50% EC BS (Table 2).

Dead seed bug Count

The analysis of variance indicated that insecticides and application methods showed significant difference on dead seed bug among treatments. The highest dead seed bug was recorded at Lipron 50 SC BS, while the lowest was recorded at control (Table 2). This result in harmony with (Kalaiyarasan and Palanisamy 2005) particularly, Malathion 50%.

Live seed bug count during threshing

The analysis of variance revealed that insecticides and application methods showed significant difference on live seed bug count during threshing among treatments. The highest number of live seed bug count was recorded at control (unsprayed), while the lowest was recorded at check (protected) (Table 2).

Thousand seed weight (g)

The analysis of variance indicated that insecticides and application method showed significant difference on thousand seed weight among treatments. The highest seed weight (3.1 g) was recorded at check (protected) followed by Malathion 50% EC CR, while the lowest (2.1 g) was recorded at control (unsprayed) (Table 2). This result in line with refrence(Kalaiyarasan and Palanisamy 2005) in case of Malathion 50%. The highest seed weight in insecticides treated could be due to their sensitivity to chemicals.

Yield kg/50 ties

The analysis of variance revealed that insecticides and application methods showed significant difference on Yield kg/50 ties among treatments. The highest yield (1.17 kg) was recorded at check (protected) followed by Lipron 50 SC and Deltamethrin spraying at base before Hila stacking, while the lowest (0.53 kg) was recorded at Control (unsprayed) (Table2).

Yield loss

The analysis of variance indicated that insecticides and application method showed significant difference on yield loss among treatments. The highest yield loss percentage (43.6%) was recorded at Malathion 5% D CR though statically similar with control (unsprayed) andMalathion 5% D BS, while the lowest (0%) was recorded at check (protected) (Table2).

Effect of seed bug on sesame seed quality

Seed bug affect seed quality by sucking as a result the seed become light in weight and content. This clearly indicated in figure 5, where the capsule kept free from seed bug infestation were healthy and unaffected, and the capsules kept in infested area were deteriorated in quality and quantity (figure 5). Higher numbers of seed per capsule (58±3) were recorded from capsules kept free of seed bug; whereas the lower seeds (33±8) was recorded at capsule kept in infested area (Figure 5.A). The rest of seeds in the infested capsule were dispersed by sesame seed bug. In the infested capsule, we record about 22±6 healthy seeds whereas 11±2 were damaged or sucked seeds (Figure 5.B).

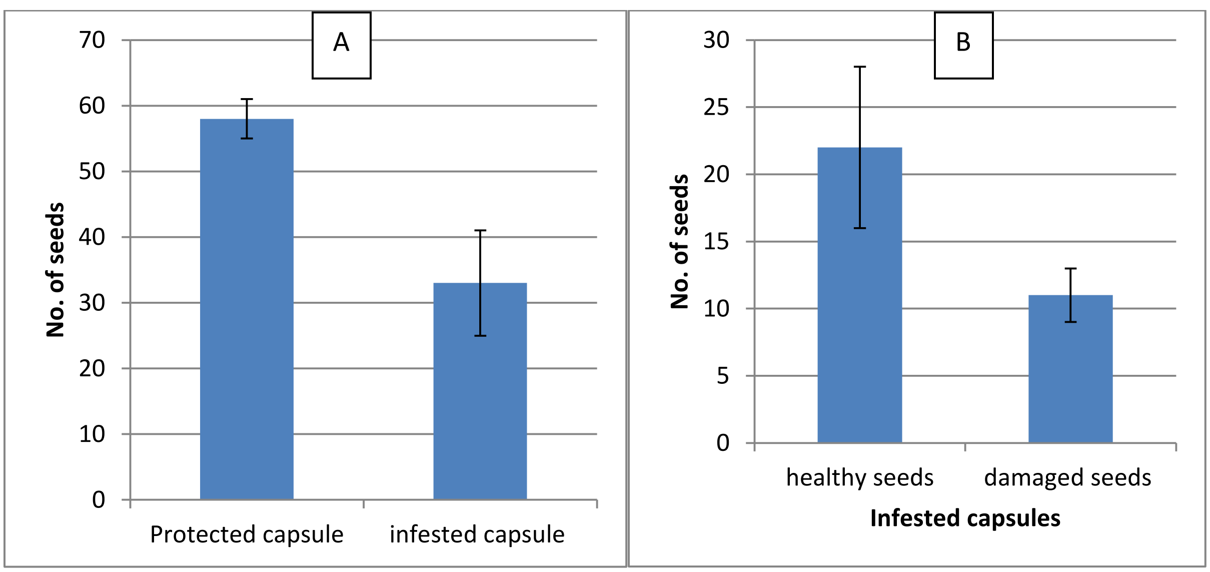

Figure 5. No.of seeds per protected and infested capsules (A), no. of healthy and damaged seeds per infested capsule (B)

Partial budget analysis

Among the 9treatment combination tested, 6 treatments were dominated and excluded from the marginal analysis (Table 3). Irrespective of the insecticides used, all circumference application method was dominated because of their non-profitability to the farmers. As compared to control (unsprayed), Deltamethrin spray at base of the stack of Hila offered 4040.13% marginal rate of return (Table 4). Again spraying Lipron 50 SC at base of Hila stack also gave MRR of 377.71% when it was compared to it preceding treatment (i.e., Deltamethrin BS). The marginal rate of return revealed that spraying of Lipron at base of a stack produce profitable return compared to its preceding treatment (Deltamethrin BS). This implies by investing 1birr produce 3.77birr with spraying of Lipron at base of Hila stack for seed bug.

Table 3. Dominance analysis of the combinations of insecticides and application method effect on sesame yield in 2011at Kafta Humera, Ethiopia

Treatment	CTV (birr)	gross benefit(birr)	net benefit (birr)	
Control	0	31.8	31.8	
Malathion 5% D BS	0.25	30.6	30.3488	D
Deltamethrin BS	0.38	47.4	47.0232	
Malathion 50% EC BS	0.38	39.6	39.2232	D
Lipron 50 SC BS	1.00	50.4	49.3952	
Malathion 5% D CR	1.26	29.4	28.144	D
Deltamethrin CR	1.88	42.6	40.716	D
Malathion 50% EC CR	1.88	37.8	35.916	D
Lipron 50 SC CR	5.02	39.6	34.576	D

Table 4. Marginal rate of return of the combination of insecticides and application method in Kafta Humera,Ethiopia.

Trt	cost of chemical	CTV	gross benefit	net benefit	MRR (%)
Control	0	0	31.8	31.8	
Deltamethrin BS	300	0.3768	47.4	47.0232	4040.13
Lipron 50 SC BS	800	1.0048	50.4	49.3952	377.71

Conclusion and Recommendation

The current investigation revealed that insecticides and application methods on sesame *Elasmolomussordidus* had a great effect. Insecticides and application methods had positive effect on thousand seed weight, yield per 50 ties and yield loss. Lipron 50%SC sprayed plot were very low in seed bug infestation up to threshing. Deltamethrin and malathion50% EC sprayed plots were effective up to 9 days after staking then infestation get increased. Where infestations in the control and malathion 5% sprayed plots were increased steeply up to 11 days then reduced at the 14 days. Higher no.of dead bugs and lower no. of live bugs were also scored in the lipron sprayed plots. Generally, application of lipron was efficient to protect seed bugs and deltamethrin was effective, where some seed bug appearance occurred after 10 days later. Lower seed yield loss (14-18%) and higher seed yield were recorded in deltamethrin BS and lipron 50%SC BS sprayed plots. Normally, application of Deltamethrin and Lipron before Hila staking was found better in protecting sesame seed bug infestations and in minimizing seed losses due to seed bug. The economic analysis also revealed that spraying of Deltamethrin and Lipron at base before Hila stacking showed profitability as compared all treatment.

Recommendations

- Therefore, these insecticides (deltamethrin 5%D and/or lipron 50%SC) with pre Hila stacking spray have to recommended to protect sesame seed bug infestations
- And application frequency for deltamethrin 5%D should 1-2 times (1^{st} before stacking, 2^{nd} spray 9 days later) according to the infestation status of the insect.

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1.5. The Effect of N and P Fertilizers on the Yield and Yield Components of Sesame (Sesamum indicum L.) in North-Western Ethiopia

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Abstract

Sesame (*Sesamum indicun* L.**)** is an important oil crop in Ethiopia and the world. Despite of its importance, the productivity of the crop is remained very low due various factors such as poor soil fertility. The objective of the study was to identify the effect of nitrogen (N) and phosphorus (P) fertilization on yield and yield components of sesame. Six levels of nitrogen and six levels of phosphorus were applied using a factorial randomized complete block design. Application of nitrogen and phosphorous significantly affected to plant height, the number of capsules plant^{-1}, and yield. The number of days to flower decreased as the rate of nitrogen increased whereas the number of days to maturity was highest (91 days) at a rate of 23 kg N ha^{-1}. The highest yield (917.8 kg ha^{-1}) and the tallest plants (104 cm ± 16 cm) were recorded at an application of 64 kg N ha^{-1}. Application of 64 kg P_2O_5 ha^{-1} resulted in the highest yield (908 kg ha^{-1}) and the tallest plants (103.4 cm ± 18.6 cm). The interaction between N and P significantly affected the number of days to flower, plant height, the number of capsules plant^{-1}, and yield ha^{-1} but did not affect the number of days to maturity. Plant height, number of capsules plant^{-1}, and yield ha^{-1} increased with increased rates of combinations of nitrogen and phosphorus. Partial budget analysis showed that application of 41 kg N and 46 kg P_2O_5ha^{-1} gave the largest marginal rate of return. Hence, it is recommend that not only the rate for N and P but also the rate for all nutrients should be investigated at different agro-ecologies and production niches of the region by taking the environmental sustainability in to consideration.

Key words: Benne, Oilseeds, Mono-cropping, Sesamum

Introduction

Sesame (*Sesamumindicum* L.) is one of the oldest oil-seed crops cultivated in almost all tropical and subtropical Asian and African countries (Langham and Wiemers 2006). Sesame seeds are a significant source of edible oil and are widely used as a spice. The seeds contain 50−60% oil which has excellent stability due to the presence of natural antioxidants such as sesamolin, sesamin and sesamol (Brar and Ahuja 1979). This warm season annual crop is primarily adapted to areas with long growing seasons and well-drained soils (Hansen 2011).

The world market of sesame seeds is a billion dollar industry that supports the livelihood of millions of farmers throughout the world (SBN 2015). In Ethiopia, more than 600,000 small-scale farmers (CSA 2009) and investors together owned more than 300,000 hectares of land involved in sesame production every year and more than 90% of the production is exported. Next to coffee, sesame seeds are the second largest source of foreign exchange in Ethiopia (Girmay 2015). Ethiopia is the first largest exporter of sesame seeds in the world and seventh in production (FAOSTAT 2017).

For many years, sesame productivity in Ethiopia remained very low due to different production constraints. Poor soil fertility is one of the most important factors limiting the productivity aggravated with poor cultural practices like mono cropping (Linden et al. 2018). The soils of the Humera plains have sustained crop production for long periods without the use of external inputs. The repeated sesame production (mono cropping) has resulted in depletion of nutrients from the topsoil with a subsequent reduction in yield. Hailemariam (2018) reported that soil analyses of the study area (North-West of Ethiopia, Humera surrounding) have very lower NP content compared to moderately fertile soil (Tekalign 1991; Cook 1967). Many researchers have shown that sesame is very responsive to nitrogen and phosphorus fertilizers (Malik et al. 2003; Ahmad et al. 2001; Ashfaq et al. 2001; Sharma and Kewat 1995; Rao et al.1994; Scilling and Cattan 1991; Adam 1986). However, such activity is not known in the study area. The objective of this study was to investigate the effect of N (urea) and P (di-ammonium phosphate (DAP) fertilizers on the yield and yield components of sesame in North-Western Ethiopia.

Materials and Methods

Field experiment

Field experiment was conducted in the Kafta Humera district in North-Western Ethiopia at Humera Agricultural Research Center ($14^{0}27^{'}$ N latitudes, and $36^{0}27'$ E longitudes) with an altitude of 604 meters above sea level in 2010 and 2011. The dominant soil reference group of the area is Vertisol (EARO 2002). Composite soil samples were collected from the top 0−30 cm depth in the two cropping seasons to determine physicochemical properties of the experimental site (Table 1). Total N was determined by the modified Kjeldahl method (Bremner 1982). Available P was estimated by using the Bray P1 method (Bray & Kurtz 1945) and afterwards determined by spectrometry, while K was extracted in 1 M NH_4OAc buffered at pH 7 (Page et al. 1982) and determined by flame photometer. Rainfall and temperature data were recorded from nearby metrological station during the growing seasons. During the growing season, the experimental site received 503 and 411.5 mm rainfall in 2010 and 2011, respectively. Temperature data of the growing seasons are shown in Figure 1.

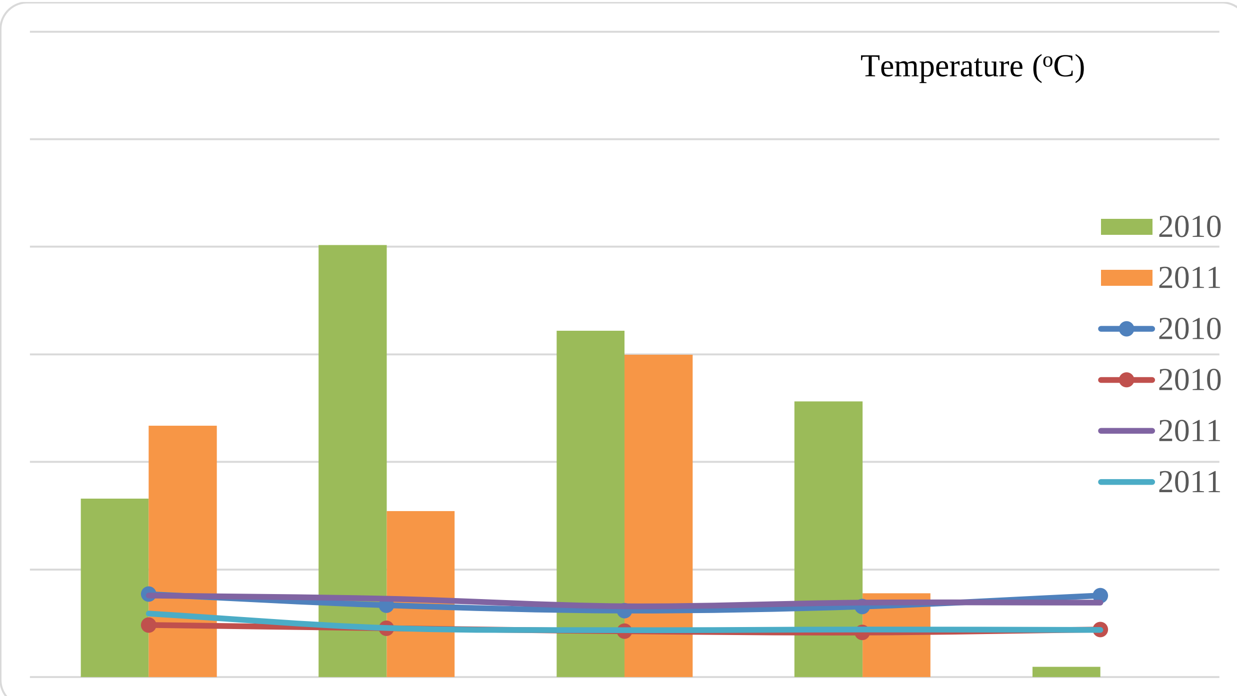

Fig.1 Rainfall distribution, minimum, and maximum temperatures of the experimental site during the growing season of 2010 and 2011.

The experiment was conducted on a site, which has been cultivated with sesame for four consecutive years. The land was ploughed and harrowed using tractor mounted moldboard before sowing. The total experimental area was 2444.4 m^2 (135.8 m x 18 m), with a gross plot size of 2.8 m x 5 m, and net plot size of 2 m x 4 m. The border rows and 0.5 m from both sides of each row were used as buffer zones to minimize the effects of external factors. Alleyways were created between the replications and between plots with a width of 1.5 m and 1 m, respectively.

The treatments consisted of six rates of urea (0, 25, 50, 100, 150, and 200 kg ha^{-1}) and six rates of diammonium phosphate (DAP) (0, 25, 50, 100, 150, and 200 kg ha^{-1}). The experiments were laid in a factorial randomized complete block designs (RCBD) with three replications. A locally commonly grown sesame cultivar called 'Hirhir' was used as test crop. The seeds were sown on

15 and 17 July in 2010 and 2011, respectively. Seeds were sown using seed drilling in rows with a row spacing of 40 cm. The seedlings were thinned to achieve 10 cm space between plants when the plants attained a height of 5 cm. The total amount of DAP and half of the total amount of N were added to the soil during sowing while the remaining N was applied as side dressing during flower initiation (28 days after emergence). Weeds were controlled manually using hoes 7, 28, and 56 days after emergence as recommended by Amare et al. (2010). There were no pest problems during the first year, but webworms were appearing in the second year and controlled by using Ethiothion (Malathion 50% EC, Adami Tulu Pesticide Processing S.C., Addis Ababa, Ethiopia) at the rate of 1.5 l ha^{-1} in 200 l of water when the flowering began. Days to flowering and maturity were recorded when 50% of the plants in a plot reached the flowering stage, and when 90% of the population turned their leaves yellow, and the lower outermost capsules started opening respectively. Each phenological stage was determined visually. From the five middle rows, five plants were chosen randomly and their final height of the main stem was measured from the ground to the apex of the main stem tip. Seed yield of each net plot was weighted and converted to yield ha^{-1} after adjusting the moister content to 7.5% (Biru 1978).

Partial budget analysis

Economic analysis was done using partial budget analysis methods as described by CIMMYT (1998). We analyzed the grain yield in order to assess the costs and benefits associated with the different treatments. Economic analysis was done using the market price for fertilizer, harvest, threshing, and for grain yield. All costs and benefits were calculated on a hectare basis in the Ethiopian currency Birr. There is a principle that says grain yield usually reduce by 10 % in farmer farms than the grain yield harvested in research managed small plots with the same input, management practice, agroecology and so on. It is easy and efficient to manage small research plots but this cannot be done similarly in larger farms and this cause 10 % yield reduction with the same input, agroecology, management practice and so on. For this reason, grain yield was adjusted down by 10% to minimize the effect of researcher managed small plots as compared to the farmers managed plots when calculating partial economic analysis. The dominance analysis procedure (CIMMYT 1998) was used to select profitable treatments from the range tested. The marginal rate of return (MRR) was calculated using equation 3 by considering a pair of non-dominated treatments listed. Non-dominated treatments are treatments giving lower net revenue compared to the treatment giving maximum net revenue but their cost is lower than the treatment giving maximum net revenue and they are included in calculating the MRR to compare cost effectiveness. MMR denotes the return per unit of investment in the change of field management tested in the field research (CIMMYT 1998). Following the analysis, treatments with the highest MRR were recommended to farmers.

Gross benefit = economical yield return *price (birr/kg)……………...………….. (Equation 1)

Net profit= gross benefit –total cost that vary…………………………………….. (Equation 2)

$$MRR = \frac{\text{change in NB}}{\text{change in TVC}}$$ ……………………………………………………….……………. (Equation 3)

Where MRR is the marginal rate of return, NB is net benefit ha^{-1} for each treatment, TVC is the total variable costs ha^{-1} for each treatment.

Data analysis

The effect of the application of fertilizers were analyzed with Analysis of Variance using SAS software version 9.1 (SAS Institute Inc. SAS Campus Drive, Cary, North Carolina 27513, USA). Whenever the treatment effects were significant, mean separations were tested using the Duncan's Multiple Range Test (DMRT) at 5% level of probability.

Results and Discussion

Physical and chemical properties of the soil

The total content of N and P was very low (0.05 g kg^{-1} and 0.001 g kg^{-1} soil, respectively) while the potassium (K) content was at an acceptable level (0.29 g kg^{-1} soil). The soil organic matter was low (0.79%) while pH was high (8.4) (Table 1).

Table 1. Physical and chemical properties of the soil (average of sample from 2010 and 2011). EC: at Kafta Humera, Ethiopia

pH	EC (ds/m)	Total N %	CEC meq 100 g^{-1}	Available P ppm	Available K ppm	OC %	OM %	Clay %	Silt %
8.35	0.36	0.046	56	0.76	290	0.46	0.79	31.9	29.0

Electrical conductivity; N: Nitrogen; CEC: Cation Exchange Capacity; P: Phosphorus; K: Potassium; OC: Organic carbon; OM: Organic matter.

Effect of N and P on growth parameters and yield

N application significantly influenced the growth parameters and yield traits of sesame. Days to 50% flowering was reduced by nitrogen fertilization. Application of 23 kg N ha^{-1} resulted in significantly slower maturation than any other N-treatment. Plots receiving 64 kg N ha^{-1} matured three days earlier that plots receiving 23 kg N ha^{-1}. Plant height increased by the increasing rate of N. The tallest plants (104.1 cm) were found in the plots fertilized with 92 kg N ha^{-1} whereas the smallest plants (90.2 cm) were found in the unfertilized plot (Table 2). Increasing N application resulted in an increasing number of capsules $plant^{-1}$ except for 69 kg N ha^{-1} (Fig. 2). The largest number of capsules $plant^{-1}$was found in plots receiving 92 kg N ha^{-1}, having 20 capsules more than unfertilized plot (Table 2). Increasing application of N increased the yield (Fig 3). The highest yield (917.8 kg ha^{-1}) was obtained at the highest rate of N (92 kg N ha^{-1}) while unfertilized plots had the lowest yield (572.8 kg ha^{-1}) (Table 2).

Table 2. The effects of N and P fertilizers on yield and yield components of sesame in 2010 and 2011 at Kafta Humera, Ethiopia.

Urea	DF	DM	PHT	NC	Yield
0	46.0^{a}	89.6^{b}	90.2^{d}	22.5^{d}	572.8
25	45.4^{ab}	89.0^{b}	99.8^{b}	32.3^{c}	710.8^{c}
50	45.0^{ab}	91.3^{a}	103.4^{a}	33.4^{c}	893.5^{a}
100	45.1^{b}	88.8^{b}	96.5^{c}	38.8^{b}	806.7^{b}
150	44.9^{b}	89.8^{b}	99.6^{b}	40.1^{b}	884.6^{a}
200	45.4^{ab}	88.4^{b}	104.1^{a}	42.8^{a}	917.8^{a}
DAP					
0	45.7^{a}	89.9	95.6^{c}	31.5^{e}	640.9^{d}
25	45.5^{ab}	89.2	95.7^{c}	34.3^{d}	741.8^{c}
50	45.9^{a}	89.8	96.8^{c}	34.5^{d}	$755.5b^{b}$
100	45.3^{ab}	89.4	98.7^{b}	37.3^{c}	845.9^{b}
150	44.9^{ab}	88.9	103.4^{a}	38.8^{b}	894.4^{a}
200	44.7^{c}	89.8	103.4^{a}	43.4^{a}	907.7^{a}
Interactions					
Year*urea	**	**	**	**	**
Year*DAP	Ns	ns	*	**	*
Urea*DAP	**	ns	**	**	**
Year*Urea*DAP	Ns	ns	ns	ns	**

*: $p<0.05$, **: $p<0.01$, ns = $p>0.05$
DF= Days to 50% flowering, DM= Days to maturity, Ph=Plant height in cm, NCPP= Number of capsules $plant^{-1}$.
Numbers with different letters are statistical significantly different.

Application of P influenced all phenological parameters except days to maturity (Table 2). In average, the control plants needed one day more to flower than plants receiving 200 kg DAP ha^{-1}. Plant height increased with an increasing rate of DAP. However, adding 200 kg DAP ha^{-1} did not increase the plant height further. Plants receiving 150 kg DAP ha^{-1} and 200 kg DAP ha^{-1} were 4.7 cm taller than the control plants (95.6 cm). Increasing DAP application also resulted in an increasing number of capsules plant^{-1}. The highest number of capsules plant^{-1} (43.4) was obtained in the plots fertilized with 200 kg DAP ha^{-1} whereas the lowest number of capsules plant^{-1} (31.5) were obtained from the control plots (without DAP). DAP application also significantly influenced the seed yield. The largest yield (917.8 kg ha^{-1}) was obtained at the largest rate of DAP (200 kg DAP ha^{-1}) while the lowest yields were recorded in unfertilized plots (640.9 kg ha^{-1}).

Interaction effect of N, P and year

Year interacted significantly with the urea applications and influencing days to flowering, days to maturity, plant height, the number of capsules plant^{-1}, and yield ha^{-1} (Table 2). There was also a significant interaction between year and DAP applications influencing all phenological and yield parameters except days to flowering and days to maturity. Interaction effects of N and P significantly influenced all the parameters except days to maturity (Table 2). Three-factor interaction (urea, DAP and year) significantly affected the yield ha^{-1} (Table 2).

The highest number of days to flowering was recorded in unfertilized plots and 46 kg N ha^{-1} with 0 kg P ha^{-1} followed by 55 kg N ha^{-1} with 23 kg P_2O_5ha^{-1}. The lowest number of days to flower (44.2) were obtained in plots receiving 38.5 kg Nha^{-1} combined with 69 Kg P_2O_5ha^{-1}, and 59 kg Nha^{-1} combined with 92 kg P_2O_5ha^{-1} (Table 3).

Table 3. Number of days to flowering at different combination of DAP and urea applications in 2010 and 2011 at Kafta Humera, Ethiopia.

Urea (kg/ha)	DAP (kg/ha)					
	0	25	50	100	150	200
0	46.8^{a}	44.2^{cd}	45.7^{b-d}	46.0^{b-d}	45.3^{b-d}	45.0^{cd}
25	45.6^{b-d}	45.8^{b-d}	47.0^{b}	45.3^{b-d}	44.2^{d}	44.7^{cd}
50	44.8^{cd}	44.7^{cd}	45.7^{b-d}	45.3^{b-d}	45.5^{b-d}	44.2^{d}
100	46.8^{a}	44.7^{cd}	46.5^{bc}	44.8^{cd}	44.5^{d}	44.5^{d}
150	44.8^{cd}	45.5^{b-d}	45.0^{cd}	45.2^{cd}	44.8^{cd}	44.3^{d}
200	45.5^{b-d}	46.0^{b-d}	45.5^{b-d}	45.2^{cd}	44.8^{cd}	45.3^{b-d}

NB. Numbers with the same letter showed significant difference at $p \leq 0.05$.

Table 4. Mean plant height (cm) at treatment combinations at 2010 and 2011 in Kafta Humera,

	DAP (kg/ha)					
Urea (kg/ha)	0	25	50	100	150	200
0	74.8^{j}	83.6^{i}	88.2^{i}	94.3^{f-h}	98.9^{d-h}	101.4^{b-d}
25	103.6^{b-d}	98.8^{d-h}	93.7^{h}	99.5^{c-g}	100.0^{c-e}	103.1^{b-d}
50	98.8^{d-h}	105.0^{bc}	102.9^{b-d}	$10.3.2^{b-d}$	105.8^{b}	104.8^{bc}
100	95.9^{d-h}	93.8^{h}	94.1^{gh}	94.2^{f-h}	98.6^{d-h}	102.2^{b-d}
150	98.3^{d-h}	93.7^{h}	102.0^{b-d}	99.5^{c-g}	102.2^{b-d}	101.9^{b-d}
200	102.0^{b-d}	99.6^{c-f}	100.1^{c-e}	101.7^{b-d}	114.7^{a}	106.8^{b}

NB. Numbers with the same letter showed significant difference at $p \leq 0.05$.

The interaction between N and P had a significant effect on the number of capsules plant^{-1} ($p<0.05$). The number of capsules plant^{-1} increased with the increasing rate of N and P. The highest number of capsules plant^{-1} (48.6) was recorded at 105 kg Nha^{-1} and 92 kg P_2O_5ha^{-1} while the lowest number of capsules plant^{-1} was recorded on non-fertilized plants (Table 5).

Table 5. Mean number of capsules plant^{-1} at different combination of DAP and urea applications in 2010 and 2011 at Kafta Humera, Ethiopia.

Urea (kg/ha)	DAP (kg/ha)					
	0	25	50	100	150	200
0	15.7^{n}	23.2^{m}	24.3^{m}	23.2^{m}	24.0^{b}	24.7^{b}
25	24.0^{m}	25.0^{m}	26.7^{m}	31.7^{l}	39.8^{g-i}	46.5^{b-f}
50	31.8^{l}	47.0^{a-d}	42.8^{e-g}	47.7^{a-c}	42.8^{e-g}	48.4^{ab}
100	38.4^{h-j}	33.8^{kl}	38.2^{h-i}	37.9^{ij}	40.1^{g-i}	44.5^{b-f}
150	35.8^{jk}	35.4^{j-l}	35.3^{j-l}	41.6^{f-i}	43.8^{c-g}	48.6^{a}
200	43.6^{d-g}	41.6^{f-i}	40.0^{g-i}	41.6^{f-h}	42.1^{f-h}	47.8^{ab}

NB. Numbers with the same letter showed significant difference at $p \leq 0.05$.

Table 6. Mean yield of sesame at different combination of DAP and urea applications in 2010 and 2011 at Kafta Humera, Ethiopia

Urea	DAP rates (kg/ha)					
rates(kg/ha)	0	25	50	100	150	200
0	423.6^{p}	555.6^{n-p}	642.8^{k-o}	688.9^{h-o}	582.8^{m-p}	780^{d-m}
25	490.2^{o-p}	650^{k-o}	834.8^{b-k}	749.1^{e-n}	699.1^{g-n}	860.8^{a-j}
50	581.6^{m-p}	672^{i-l}	835.3^{a-k}	667.9^{j-o}	881.1^{a-h}	831.5^{b-l}
100	594.6^{m-p}	706.4^{f-n}	984.6^{a-d}	819.6^{c-l}	825.5^{b-l}	936.1^{a-e}
150	625^{l-p}	844.8^{a-k}	1030.4^{ab}	897.6^{a-g}	987.7^{abc}	877.4^{a-i}
200	665^{j-o}	816.6^{c-l}	945.6^{a-e}	907.3^{a-f}	992.9^{a}	1042.6^{a}

NB. Numbers with the same letter showed significant difference at $p \leq 0.05$.

Partial budget analysis

Among 36 treatments of N and P interaction, 13 treatments were dominated and excluded from the MRR analysis calculation (Table 7). Dominated treatments are the treatments giving lower net revenue compared to the treatment giving maximum net revenue while their cost increasing and they are excluded from calculating MRR since they are not cost effective.

Table 7. Dominance analysis for interaction effect of DAP and urea rate on sesame in 2010 and 2011 at Kafta Humera, Ethiopia

S.N	DAP	Urea	Total revenue	TVC	Net revenue
1	0	0	19062	0	19062
2	0	25	25002	400	24602
3	25	0	22059	425	21634
4	0	50	28926	800	28126
5	25	25	29250	825	28425
6	50	0	26172	850	25322
7	25	50	37566	1225	36341
8	50	25	30240	1250	28990
9	0	100	31000.5	1600	29400.5
10	50	50	37588.5	1650	35938.5
11	100	0	26757	1700	25057
12	25	100	33709.5	2025	31684.5
13	100	25	31788	2100	29688
14	0	150	26226	2400	23826
15	50	100	30055.5	2450	27605.5
16	100	50	44307	2500	41807
17	150	0	28125	2550	25575
18	25	150	31459.5	2825	28634.5
19	150	25	38016	2950	35066
20	0	200	35100	3200	31900
21	50	150	39649.5	3250	36399.5
22	100	100	36882	3300	33582
23	150	50	46368	3350	43018
24	200	0	29925	3400	D 26525
25	25	200	38736	3625	D 35111
26	200	25	36747	3800	D 32947
27	50	200	37417.5	4050	D 33367.5
28	100	150	37147.5	4100	D 33047.5
29	150	100	40392	4150	D 36242
30	200	50	42552	4200	D 38352
31	100	200	42124.5	4900	D 37224.5
32	150	150	44446.5	4950	D 39496.5
33	200	100	40828.5	5000	D 35828.5
34	150	200	39483	5750	D 33733
34	200	150	44680.5	5800	D 38880.5
36	200	200	46917	6600	D 40317

Note: TVC stands for total variable cost which are N and P. Below S.no 23 are dominated and denoted by D since the profit is decreasing but cost is increasing and these are excluded from calculating MRR in Table 8.

Different N and P levels were dominated and excluded from calculating MRR since it can be seen from the table the cost is increasing but their net revenue is decreasing from the highest net revenue so they are not profitable to the farmers (Table 8).

Table 8. Partial Budget analysis of DAP and Urea interaction in 2010 and 2011 at Kafta Humera

S.N.	DAP and urea interaction		TVC	Net revenue	MRR %
	Kg DAP ha^{-1}	Kg urea ha^{-1}			
1	0	0	0	19062	---
2	0	25	400	24602	1385
3	25	0	425	21634	-11872
4	0	50	800	28126	1731.2
5	25	25	825	28425	1196
6	50	0	850	25322	-12412
7	25	50	1225	36341	2938.4
8	50	25	1250	28990	-29404
9	0	100	1600	29400.5	117.2857
10	50	50	1650	35938.5	13076
11	100	0	1700	25057	-21763
12	25	100	2025	31684.5	2039.231
13	100	25	2100	29688	-2662
14	0	150	2400	23826	-1954
15	50	100	2450	27605.5	7559
16	100	50	2500	41807	28403
17	150	0	2550	25575	-32464
18	25	150	2825	28634.5	1112.545
19	150	25	2950	35066	5145.2
20	0	200	3200	31900	-1266.4
21	50	150	3250	36399.5	8999
22	100	100	3300	33582	-5635
23	150	50	3350	43018	18872

Note: TVC stands for total variable cost which are DAP and Urea. MRR stands for marginal rate of return.

Discussion

The response of sesame to different rates of N and P fertilizers was evaluated under the semi-arid conditions of Kafta Humera, North-West Ethiopia. The application of N and P significantly influenced both growth and yield parameters. Plants receiving both fertilizers flourished earlier than the unfertilized plants. This finding is contradicting to the results of Fathy and Mohamed (2009), who found that the number of days to flowering increased as the rate of fertilizer increased. Days to maturity was significantly influenced by different rates of both nitrogen and phosphorus fertilizers. Days to maturity increased as the rate of nitrogen increased up to 23 kg N ha^{-1} but days to maturity was not influenced by P application. This might be due to the low impact of phosphorus on the vegetative growth of sesame.

Plant height was significantly affected by the application of nitrogen and phosphorus. Generally, plant height increased as the rate of both fertilizers increased. The largest number of capsules plant^{-1} were obtained from the plots receiving the highest rate of both nitrogen and phosphorus. Abdel Rahman and El Mahdi (2008) also found that increasing level of N and P resulted of increasing plant height and number of capsule plant^{-1} for 'Shuak' variety of sesame grown under almost the same condition in Northern Sudan. Our results are also in line with studies of Kashani et al. (2015) in Pakistan who used two different varieties (S-17 and Pr-125). They also observed the tallest plants and largest number of capsules plant^{-1} at the highest rates of N (70 kg ha^{-1}) and P (70 kg ha^{-1}).

The interaction between nitrogen and phosphorus significantly affected the productivity of sesame. Seed yield ha^{-1} increased when both fertilizers increased. Javaid*et al.* (2015) used a different variety (Black) but observed the same in Pakistan. They found that the interaction between N and P resulted in the highest yield at the highest rate of treatments (100 kg urea ha^{-1} and 80 DAP kg ha^{-1}). Muhammad *et al.* (2016) also reported from an experiment in Pakistan, Peshawar valley, that increasing combination of N and P fertilizer increased the yield (90 N kg ha^{-1} and 90 kg P ha^{-1}).

The significant difference between the yields in 2010 and 2011 was probably due to differences in rainfall. Rainfall in 2010 was 503 mm, which is close to the optimum moisture requirement (600 mm) (Hansen 2011) while it was only 411.5 mm in 2011. The highest MRR% was (28403 birr) obtained from 46 kg P_2O_5 ha^{-1} and 41 kg N ha^{-1} (Table 8). This indicates that farmer can obtain 284.00 birr extra by investing one birr on buying fertilizer for application of 46 kg P_2O_5 ha^{-1} with 41 kg N ha^{-1} rate. This mean investing one birr will earn 284.00 birr when using 46 kg P_2O_5 ha^{-1} with 41 kg N ha^{-1} rate.

Conclusion

Many fields at the Humera plains in Ethiopia have a high pH and have been grown with sesame in monoculture for many years without the use of fertilizer resulting in depletion of nutrients from the topsoil and subsequently reduction in seed yields. Our experiments showed that adding N and P fertilizer could increase the yield considerably. However, as the farmers in this area have limited resources, we would only recommend adding approximately 46 kg P_2O_5 ha^{-1} and 41 kg N ha^{-1}. Added more did not improve the yield in such a way that it would justify an investment in more fertilizer. From this finding, it is recommended that not only the rate for N and P but also the rate for all nutrients should be investigated at different agro-ecologies and production niches of the region by taking the environmental sustainability in to consideration.

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1.6. Evaluation of Different Planting Methods on Yield and Yield Components of Tef [EragrostisTef (Zucc.) Trotter] in Central Zone of Tigray, Ethiopia

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Abstract

The low national tef productivity is mainly attributed due to lack of improved agronomic practices. The objectives of the study were to determine the optimum seed rate of row, broadcasting and in intra and inter row spacing of tef transplanted planting. A field experiment was carried out at Laelay maychew and Naederadet for two years. The experiment was laid out in RCBD with three replications having 3×3 (9 m^2) and seven treatments. The analysis of variance showed that there is a significance difference at ($P \leq 0.001$) for days to maturity, plant height, panicle lengthand grain yield. The lower seed rate and wider inter and intra row spacing of direct and transplanting planting method had a significantly affected on the days to maturity, plant height, panicle length and grain yield. Tef grain yield increases 20x15cm intra and inter row spacing and use of lower seed rate for both direct planting methods (broadcasting and row planting). The planting methods did not show a statistically a significance difference among them. The optimum seed rate for broadcasting was 5kg/ha, while the row planting also 20x15cm spacing by 5kg/ha seed rate and the transplanting method with spacing of 20x15cm. Therefore, depending different conditions use of all panting method for tef production is important in the study area and similar agro ecologies. Further tef planter machine development for lower seed rate is needed.

Key words: Tef transplanting, seeding rate, row spacing.

Introduction

Tef [Eragrostis tef (Zucc.) Trotter], has genetic origin and center diversity in Ethiopia (Vavilov 1951). It is an important staple cereal crop in Ethiopia occupying more than three million hectare of land. This crop is first in area coverage but second and last in production and productivity, respectively, from cereals under production in Ethiopia. It is grown by over 6.6 million households and constitutes the major staple food grain for over 50 million Ethiopians (CSA 2015).Nutritionally, tef has been receiving global attention as health food because of its gluten-free nature that renders it suitable for people suffering from gluten allergy known as celiac disease (Spaenij *et al*. 2005) and slow release of carbohydrates that makes it suitable for diabetic people (FAO 2015). Antibody-based assay have shown that tef does not contain the offending epitopes (Spaenij et al. 2005). Tef has high iron content that makes it suitable for pregnancy-related and hookworm infestation related anemia (Alaunyte et al. 2012). The iron content seems to play a particularly important role in Ethiopia, as absence of anemia has been found to correlate with areas of tef consumption (BoSTID 1996).

However, the current low yield levels can be attributed to different production constraints such as susceptibility to lodging, moisture stress, and poor agronomic practices, pre- and post-harvest management practices (Abraha 2016). One of the most limiting factors for tef production is planting methods and level of seed rate. The current productivity of tef is 1750kg/ha nationally whereas, in Tigray region is 1537kg/ha. However, the attainable yield potential is 6000kg/ha (Seyfu 1993). The planting methods such as broadcasting, row planting and transplanting is yet identified the optimum plant population per unit area for the production of tef before, this study. The broadcast method of sowing has been predominantly used in a long time. It has been argued that more efficient agronomic management could double the yield of crop plants (Mueller et al. 2012). Broadcast associated with a high incidence of lodging, reduced plant growth and yield (Asargew et al. 2014), lodged plant tef reduced its grain quality and straw when higher seed rate is used. However, the productivity of tef can increase through estimation of the appropriate planting method and level of seed rate and intra row spacing of transplanted.

The row planting and transplanting method of a month age tef seedlings are one of the promising planting techniques to boost the yield of tef (Kebebew et al. 2011; Seyfu 1997). Transplanting is assumed to have the benefits of escaping dry spells occurring in any particular season and enhancing productivity under dry land areas. Transplanting in a row considerably increased the seed yield and reduces the seed rate compared with the broadcasting method that a farmer uses 25 to 50 kg/ha tef as compared to transplanting required only 2 to 2.5kg/ha (Tareke et al. 2013). In addition to this it also increases number of productive tillers. Whereas, in transplanting seedling the wider spacing give the higher gran yield, this spacing gives the chance of the plant to grow optimum environment for resource uptake (Zewdie 2010).

Determining the effect of row planting, broadcasting with different level of seed rate, row spacing and transplanting intra row spacing might be significantly affect yield and yield component. Tef gran yield increase by determining the difference between the planting method and seed rate level, inter row spacing for row planting and intra row spacing for transplanted seedlings. Therefore, the present study was conducted to determine the optimum planting methods, seed rate and plant population in intra row spacing of transplanted.

Materials and Methods

The field experiment was carried out at Axum Agricultural Research Center (AxARC) in LaelayMaychew (vertisoil) and Naeder-adet (light soil) districts of the Central Zone of Tigray, Northern Ethiopia, during the main production season of (July-November) 2012 and 2013. The sites are located at 250 km and 284 North West of Mekelle and 1024 and 1069 km North of Addis Ababa at a latitude of 14°07' 235" and 13°06'762"N, at a longitude of 038°43'987'' and 038°48'38'' E, at an altitude of 2118 and 2121 m.a.s.l, respectively. The experiment was layoutby the design RCBD with three replications and plot size of 3 m length and 3 m width (9 m2) and spaces between plot and replication was 1 and 1.5 m, respectively.

Variety Quncho was used as an experimental material with the different seed rates. The treatments were (1) broadcasting at 5 kgha-1, (2) broadcasting at 25 kgha-1, (3) 15 cm, and (4) 20 cm of inter row spacing at 5 kg ha-1 seed rate for row planting and (5)10, (6)15, and (7) 20 cm intra row spacing and 20 cm inter row spacing for transplanting methods. Both the broadcasting and row planting were planted by hand drilling left on the surface little bet compacted by labors. The inter row spacing for row planting method were adjusted as 15 and 20 cm whereas for transplanting 20 cm inter row and 10, 15 and 20 cm intra row spacing were used. The treatment combinations are structured in Table1.

According to the recommendation, tef fertilizer application for black soil 60 kg ha-1 P2O5 and N at Laelaymaychew (Hatsebo) was applied and 60 kg ha-1 P2O5 and 40 kg ha-1 N also for light soil at Naeder–adet was applied (Seyfu 1997). DAP was applied at planting and urea was applied in two splits, half at the time of planting and the remaining half at tillering stage. Seedling for transplanting was grown in a bed and transplanted to experimental plot at one-month age (about three to four leaf stage), with three seedlings per hill at the spacing per the treatment. The time of transplanting was in the morning for better survival of the seedling. The experimental materials were sown on the second week of July 2012 and 2013 main production seasons. All other pre and post-planting management practices were done in accordance with the research recommendations for tef production in the area.

Days to maturity were determined from 50% seedling emergence to 90% physiological maturity. Plant height in centimeters was measured from the base of the plant to the tip of the panicle on the primary tiller of five randomly selected plants per plot. Panicle length of the central tillers in centimeters was measured as the average length of the panicle from the node where the first panicle branch starts to the tip of the central tiller of five randomly selected plants per plot. Whereas, the grain yield (kg ha-1) weighed the grain harvested from entire plot and the average was used to statistical analysis. Data were collected on plant and plot based and analyzed by SAS software version 9.1.3 (SAS Institute Inc. 2004) to evaluate the variance and mean separation using LSD at alpha level$\alpha \leq 0.05$.

Table 1. The list of treatments and their combination

S.no	Planting methods	Seed rate (kg/ha)	Inter row spacing(cm)	Intra row spacing(cm)
1	Broadcasting	5		
2	Broadcasting	25		
3	Row planting	5	20	
4	Row planting	5	15	
5	Transplanting		20	10
6	Transplanting		20	15
7	Transplanting		20	20

Results and Discussion

The analysis of variance (ANOVA) shows there was a statistically significant difference at ($P \leq 0.001$) for days to maturity, plant height, panicle length and grain yield. The late maturity113 to 115days were recorded from the lower seed rate of broadcasting 5kg/ha, 5kg/ha with 20 inter row planting and 20x20cm inter and intra row spacing of transplanted tef plants. This finding indicated that at all planting method with a lower seed rate and a wider inter and intra row spacing influenced the days to maturity. However, the higher seed rate and the narrower inter and intra row spacing shown that early days to maturity, 96 to 97 days these were broadcasting 25kg/ha, row planting 15cm inter row spacing and 20x10 and 20x15cm intra row spacing of transplanted tef population (Table 2.). This implies that the lower seed rate and the wider spacing of inter and intra row spacing optimizing the tef population per unite area that causes to grow the tef plants without external influence to early maturity. Whereas, the higher seed rate and narrower inter and intra row spacing forced to mature earlier due to the higher competition between the tef plants per unit area for resource and replace their generation. The planting method did not show a statistically significance difference among the planting methods for days to maturity. Abraham et al (2014) reported that the lower seed rate prolongs for days to maturity. In contrast to the present finding Bekalu and Tenaw (2015) reported that broadcasting planting method late matured than row planting.

Table 2. The combined mean performance of tef yield and yield components evaluated by the different planting methods, seed rate, inter and intra broadcasting, row planting and transplanting at LaelayMaychew and NaederAdet in 2012 and 2013, Ethiopia

Treatment	DM (days)	pH (cm)	Pan (cm)	Gy (kg ha^{-1})
Broadcasting at 5 kg/ha	113.92[a]	122.18[ab]	49.63[ab]	2547.20[a]
Broadcasting at 25 kg/ha	95.92[b]	104.91[c]	43.63[c]	1719.70[b]
Row planting (20 cm) at 5 kg/ha	115.08[a]	122.97[ab]	49.88[ab]	2279.00[a]
Row planting (15 cm) at 5 kg/ha	97.17[b]	108.51[c]	43.23[c]	1723.90[b]
Transplanting (20×10 cm)	97.33[b]	113.23[bc]	46.63[bc]	2134.20[ab]
Transplanting (20×15 cm)	97.00[b]	123.54[ab]	51.45[a]	2456.20[a]
Transplanting (20×20 cm)	113.58[a]	131.40[a]	53.98[a]	2586.50[a]
Grand mean	104.28	118.10	48.35	2206.65
CV	9.93	12.60	11.35	33.11
LSD	8.44	12.14	2.39	595.92
R-square	0.64	0.56	0.61	0.42
Treatments × locations($\alpha \leq 0.05$)	0.3103	0.0768	0.0080**	0.5597[ns]
Treatments($\alpha \leq 0.05$)	<0.0001**	0.0004**	<.0001**	0.0118*
Location($\alpha \leq 0.05$)	<.0001**	<.0001**	0.0035**	0.0002**

DM: Days to maturity, pH: plant height, Pan: panicle length, Gy: grain yield, * and ** significance, p<0.05 and p<0.01, respectively

The longest plant height 131 to 122cm was obtained from the wider intra row spacing of transplanting 20×20 cm, 20cm of inter row spacing of in row planting method and 5kg/ha broadcasting. In similar to the days to maturity the plant height was affected by the lower seed rate and wider inter and intra tow spacing than the planting method. However, the higher seed rate and the narrow inter and intra row spacing cause to shorter plant height 105 to 113cm. The longer plant height produces the longer panicle length directly correlated a greater number of seeds per the panicle so increases the grain yield. Moreover, the longer panicle was from the wider intra row spacing and lower seed rate. This also influenced as lateness for days to maturity and length of plant height.

The higher grain yield was obtained from the wider spacing of 20x20cm transplanting, 20cm inter row spacing of row planting method and lower seed rate of broadcasting, 2586kg/ha, 2547kg/ha and 2279kg/ha respectively of the planting methods (Table 2.). But the lower grain yield was from the higher seed rate of broadcasting, narrow inter row spacing, 1719kg/ha and 1723kg/ha respectively. This finding indicated that the production of tef grain yield influenced by the number of plants per unit area to grow with optimized population rather than the planting methods. This finding shown that the planting methods did not shown a statically significance difference among the planting methods. Therefore, depending in different factors tef producer can use all planting methods. In the study area and similar agro ecology, when the farmland is inapplicable for row planting and transplanting using broadcasting with a lower seed rate increase the productivity of tef.

The second factors/condition also, in areas which are suitable for row planting and precise row planter is available tef producer can use row planting with lower seed rate. In the last the third factors/condition would be in tef growing areas faced with erratic rain fall mean early drought, transplanting tef seedling increase grain yield. Eventhough, it is time consuming and labor intensive and no statistically significance difference with other methods Abraha et al. (2016) reported that transplanting maximized the yield of tef, but a cost-benefit analysis showed that row sowing was more profitable.However, the following authors Tareke et al. (2013) and Fekremariamet al. (2014) was reported that against the present finding.The higher grain yield with wider spacing agreed with report of (Zewdie,2010).. Practically, the lower seed rate on small scale farming had a draw back in establishing of seedling with erratic rain fail in Tigray regional state; unless, there is development of tef planter. The results depend on the condition that low seed rate and transplanting increase the productivity of tef. However, the present finding had a limitation with partial budget analysis.

The combined mean of each shows that the longer days to maturity (115days) was recorded from broadcasting @5kg/ha at Hatsebo, while the short days to maturity also at N/adet 88 days on broadcasting @25kg/ha. The longer plant height 133.77cm measured from transplanting of 20x15 at N/adet. Moreover, the shorter plant height was from Hatsebo at 25kg/ha of broadcasting. Similarly, to the plant height the longer panicle length was recorded from transplanting 20x15cm with value of 55.63cm, whereas, the shorter panicle length was 39.8cm at row planting with 15cm inter row and 5kg/ha. The higher yielding was 20x15cm at 5kg/ha of seed rate at N/adet (Table 3.). The individual valueis not so important for recommendation because of the treatment by location did not show statistically significance difference. Therefore, the average performance of the treatment over all location and season is enough to use for both locations.

Table 3. The list of mean performance of days to maturity, plant height and grain yield of 2012 and 2013

	Treatments	DM		PH		Pani		Grain yield	
		Hats	N/adet	Hats	N/adet	Hats	N/adet	Hats	N/adet
1	Broadcasting at 5g/ha	114.83	113	120.93	123.43	51.9	47.37	2501.83	2592.59
2	Broadcastingat25kg/ha	103.17	88.67	92.13	117.7	41.8	45.47	1219.11	2220.28
3	Row planting (20cm)at 5kg/ha	117.17	113	120.1	125.83	51.3	48.47	1726.35	2831.62
4	Row planting(15cm) at 5 kg/ha	105.5	88.83	100.3	116.73	39.8	46.67	1465.19	1982.53
5	Transplanting (20×10 cm)	104.5	90.17	94.57	131.9	41.2	52.07	1681.38	2586.99
6	Transplanting (20×15 cm)	104	90	113.32	133.77	47.27	55.63	2222.22	2690.23
7	Transplanting (20×20 cm)	114.67	112.5	126.67	136.13	52.47	55.5	2433.17	2739.73

DM= days to maturity, PH =plant height, Pani=panicle length

Conclusion

There was no a statistical significance difference between planting methods (broadcasting, row planting and transplanting). Therefore, all planting methods had important in tef production with in different conditions. For the direct sowing methods, the lower seed rate increases a grain yield. Whereas, the transplanting the wider inter and intra row spacing was the higher grain yield scored. Since did not shows statistically significance difference between 15 and 20cm intra row spacing use of 20x15cm reduce the space between plants minimize the weed infestation. Therefore, for potential tef growing environments the direct tef planting methods with lower seed are increase grain yield. Even though the transplanting is labor consuming (Abraha et al. 2016) in areas faced with early drought with spacing of 20x15cm is optimum for tef production under transplanting. However, the low seed rate had a problem of tef seedling establishment at large farm field and moisture limiting condition. Unless, there is a precise tef planter for production row planting for small scale former is not suitable and effective. The second reason for the low seedling stand establishment is due to unevenly distribution of seeds during sowing. Thus, use of low seed rate might be solved using manually or motor-driven broadcaster or drill in available for both large and small scale farmers.Depending on the field condition lower seed rate of broadcasting (5kg/ha), row planting(20cm inter row spacing and 5kg/ha seed rate and 20x15 spaced transplanting would be enhance the productivity of tef in the study area and similar agro-ecology

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1.7. Estimation of Different Seed Rates on Yield and Yield Components of Tef [Eragrostis Tef (Zucc.) Trotter] In Northern Ethiopia

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Abstract

Tef is a major staple cereal crop in Ethiopia. However, its productivity is limited, amongst others, by the use of improper sowing methods and inappropriate seed rates. The objective of the study was to determine the optimum seed rates of tef sown in rows and broadcast planting. A field experiment was carried out at Laelaymaichew and Naederadet districts during the 2012 and 2013 main cropping seasons. The experiment was laid out in RCBD with three replications for two sowing methods (row and broadcast) and seven seed rates (2.5, 5, 7.5, 10, 15, 20 and 25 kg ha-1).The combined analysis of variance of seed rate shown significantly affected for days to maturity, plant height, panicle length and number of productive tillers and grain yield. The planting method did not show a statistically significance difference. Highest grain yield of 2350.1 kg ha-1 ha^{-1} was obtained at seeding rate of 7.5 kg ha-1^{1} followed by 10 kg ha-^{1} row planting and 25 kg ha^{-1}broadcast methods and recorded grain yield of 2284.7 and 2291.2 kg ha^{-1}, respectively. Accordingly, 7.5- 15kg ha^{-1} seed rate row planting at a spacing of 0.2cm between rows found to be optimum for the production and productivity of tef. Whereas, for the broadcasting planting method 15kg/ha was the optimum. Depending on soil type for clay loam soil texture 7.5 to 10 kg/ha while for silt loam seed rate from 10 to 15kg/ha of row planting improve tef productivity. To enhance the production of tef in the region as well as in nation understanding the soil moisture content for planting, soil texture, soil compaction level and time, precise tef planter machine development needed.

Keywords: Tef**,** Seed rate, Planting method, Inter-row spacing

Introduction

Tef is a major staple cereal crop in Ethiopia. It composes the majority of staple food, and production and area covered by cereal crops in the country as well as in the region. However, the productivity in Ethiopia in general and at Tigray in particular is low as compared to other cereal crops (CSA 2017). The factors affecting tef productivity include use of insufficient agricultural inputs, lack of well adaptable and high yielding cultivars (Assefa et al. 2011) and most occasionally ineffective management practices such as use of high seed ratewhich causes lodging(Tareke et al. 2013), lack of proper crop and soil management practices (Tesfa et al. 2013).

One of the most problems in tef production is inappropriate tef seed rate and planting methods. Different authors conducted a research in tef seed rate in different locations (Sakatu and Adane 2017; Bekalu and Arega, 2016; Sate and Tafese 2016; Amare and Adane, 2015; Fanuel et al. 2012) Sate and Tafese also studied planting methods in addition to the seed rate levels. Except the Sakatu and Adanes reported that grain yield was not show a statically significant difference by the different level of seed rate the remained authors reported that presence of statically significance different on yield and yield components of tef. The seed rate varies from 5 to 15kg/ha in these study areas.

However, Farmers' seeding rates is ranging between 20 kg /ha in Sendafa Aleltu and 120 kg/ha in Debre Tabor area (Kenea et al. 2001). Tefera and Belay (2006) reported the use of higher seed rate would be due to it is difficult to distribute the seed evenly, the viability of farmers' own seed is reduced (i.e. uncertainty of the germination percentage), and to suppress weeds at early stages. Early in the field tef research was studied on seed rate at different location of the country. It is at Jima (Tesfa and G/mariam, 1986), Kobo (Abuhay and Haile Mariam 1986) and the rate varied from 10 to 40kg/ha. Fufa et al. (2001) concluded that despite of increasing seed rate increases yield, predominantly result of seed rate trials did not shows a statically significant different in grain yield. However, research recommendation varying by environment ranged from 20-30kg ha^{-1} (Legesse, et al. 1992; Hailu and Chilot 1992).

Mostly hand- broadcast seeding is the traditional sowing method for tef and is practiced by all farmers (Legesse et al. 1992). The determining optimum seed rate for broadcasting and row planted tef is found vital. However, practically, the present tef production system faced a problem use of the lower and higher seed rate in erratic rain fall. The lower seed rate causes to low germination (kenea et al. 2001),high weed infestation(Seyfu 1997) it is lobar consuming and uneven distribution per unit area (Seyfu 1993).Whereas, it has advantage when the farm has good moisture content, if precise tef planter machine developed appropriately hand drilling and well established seedling to use the resource effectively. While, the higher seed rate is higher competition between the plants per the unit area for resources (sunlight, water and nutrients etc.) and as well as causes for lodging (Tareke et al. 2013). Despite of the higher seed rate had higher competition it suppressed weed, good distribution and high rate of survival in moisture limiting conditions.

The row planting in moisture limiting area serves as moisture conserving mechanism enhance the germination, effective fertilizer application and weeding management with developing appropriate planter. Whereas, it limitation is due to the un precise planting method the row planting increase the seed rate(in farmers field observation), the traditional ploughing causes to deep planting, low germination and poor field establishment. Farmers in areas with black soil and faced with erratic rain fall are experienced with soil compaction during planting tef and after germination per the condition on the field of moisture content (Seyfu 1997). Therefore, row planting without compaction caused to fail good seedling establishment.

Therefore, evaluation of the different seed rate levels and planting methods to improve the agronomic management practices of tef might enhances the production and productivity tef through creating favorable environments forbetter growth and development.The present finding looks weather the seed rate and planting method have an effect per different soil type i.e clay loam (Hatsebo) and silt loam (N/adet) on yield and yield related traits.Hence, optimizing seed rates for tef sown in different soil types signifies its productivity. Considering the above facts, the study was undertaken to determine the optimum seed rates of tef sown in rows and broadcasting.

Materials and Methods

The field experiment was carried out at Axum Agricultural Research Center (AxARC) in LaelayMaichew (clay loam) and Naeder-adet (silt loam) (Unpublished data) districts of the Central Zone of Tigray, Northern Ethiopia, during the main production season of (July-November) 2012 and 2013. The sites are located 250 Km and 284 North West of Mekelle and 1024 km and 1069 Km North of Addis Ababa at a latitude of $14^0$07' 235" and $13^0$06'762"N, at a longitude of $038^0$43'987'' and $038^0$48"38 E, at an altitude of 2118 and 2121 m.a.s.l, respectively. The experiment was lay down by the design RCBD with three replications and plot size of 3m length and 3m width with ten rows ($9m^2$) and having spaces of between plot and replication was 1m and 1.5m respectively. Variety Quincho was used as an experimental material with the different seed rates:- these are 2.5, 5, 7.5, 10, 15, 20 and 25 kg $ha^{-1}$for both broadcasting and row planting. The treatment combinations are presented in (Table 1).

Table 1. The list of treatment combinations at N/adet (Tabia Selam) and T/maichew (Hatsebo) 2012 and 2013.

S.no	Planting method	Seed rate level(kg/ha)	S.no	Planting method	Seed rate level(kg/ha)
1	Broadcasting	2.5	8	Row planting	2.5
2	Broadcasting	5	9	Row planting	5
3	Broadcasting	7.5	10	Row planting	7.5
4	Broadcasting	10	11	Row planting	10
5	Broadcasting	15	12	Row planting	15
6	Broadcasting	20	13	Row planting	20
7	Broadcasting	25	14	Row planting	25

According the recommendation of 60kg/ ha P_2O_5 and N fertilizer at Laelaymaychew (Hatsebo) was applied and 60kg/ ha P_2O_5 and 40 kg ha^{-1}N also at Naeder –adet was applied (Seyfu 1997). DAP was applied at planting while urea was applied in two splits, half at the time of planting and the remaining half at tillering stage. The experimental materials were sown on second week of July 2012 and 2013 main production seasons. All other pre and post-planting management practices were done in accordance with the research recommendations for tef production in the area. The data were collected on plant and plot based and analyzed by SAS software to evaluate the variance and mean was compared using least significance difference (LSD).

Days to maturity were determined from 50% seedling emergence to 90% physiological maturity. Plant height in centimeters was measured from the base of the plant to the tip of the panicle on the primary tiller of five randomly selected plants per plot and the average was used for statistically analysis. Panicle length of the central tillers in centimeters was measured as the average length of the panicle from the node where the first panicle branch starts to the tip of the central panicle of five randomly selected plants per plot and the average was used for statistically analysis. Productive tillers were a plant raised from base of the main plant and counted from the five randomly selected plants. Whereas, the grain yield weighed the grain harvested from entire plot and the average was used to statistically analysis.

Results and Discussion

The combined analysis of variance shows there was a statically significance difference among treatments except for the panicle length. Traits like days to maturity, plant height, number of productive tillers and grain yield computed significant variation at (P<0.05).This finding indicated that the lower seed rate had relatively late maturing days 103 on both planting methods (Table 2.).

Table 2. The combined mean performance of tef yield and yield components

Planting methods and seed rates	Dm(days)	Ph(cm)	Pan(cm)	Tiller(#)	Grain yield(kg/ha)
Broad cast at 2.5 seed rate	103.33a	117.02abc	49.66	7ab	2000.50cd
Broad cast at 5 kg seed rate	102.75ab	113.73bc	46.93	5.06cde	2110.28bcd
Broad cast at 7.5 kg seed rate	102.16abc	117.36abc	47.85	6.10abc	2106.24bcd
Broad cast at 10 kg seed rate	101.58bcd	113c	46.40	5.41bcde	2035.08cd
Broad cast at 15 kg seed rate	100.41d	112.63c	45.40	4.11e	2132.99bcd
Broad cast at 20 kg seed rate	101.25cd	115.65abc	47.36	5.86abcd	2102.59bcd
Broad cast at 25 kg seed rate	101.25cd	114.3bc	46.88	4.65cde	2126.19bcd
Row plantingat2.5kgseed rate	103a	120.61a	49.18	7.51a	2179.17abc
Row planting at 5 kg seed rate	103a	118.66ab	48.48	6.26abc	2189.66abc
Row planting at7.5kgseed rate	101.4167cd	118.81ab	48.35	5.65bcde	2350.10a
Row planting at10kgseed rate	101.58bcd	118.61ab	48.25	5.48bcde	2284.71ab
Row planting at15kgseed rate	101.33cd	114.76bc	47.95	4.900cde	2162.81abc
Row planting at20kgseed rate	101.25cd	118.5ab	47.56	4.26de	1948.58d
Row planting at25kgseed rate	101.33cd	115.61abc	47.11	4.30de	2291.18ab
Gran Mean	101.82	116.37	47.67	5.47	2144.29
CV	1.461	5.42	7.15	39.16	11.31
LSD	1.203	5.11	2.76	1.73	196.39
R-square	0.95817	0.7016	0.6488	0.5326	0.8390
Treatment x location	Ns	Ns	0.926ns	0.5893ns	0.0733ns
Treatments	0.001	0.04	0.233ns	0.0023	0.0042**
Location	0.001	0.001	<.0001	0.0006	

**= Significant difference, DM=Days to maturity, Ph=Plant height, Pan=Panicle length and Tiller (#) =Number of tillers

The lower seed rate was caused to grow the plant per the potential of the crop. Therefore, the minimum seed rate optimizes and lengthens the days to maturity. Whereas, relatively the earlier was recorded from the maximum seed rate. The planting method did not show statistical significance difference rather the rate influence the maturity.Abraham et al (2014) stated that decreasing the seeding rate significantly prolonged days to maturity of the crop which was similar with present study. In contradiction to present study, Bekalu and Tenaw (2015) reported that a broadcasting planting method later matured than the row planting.

The longer plant height was scored from the lower seed rate of the both planting methods. Mainly, the broadcasting shown that the lower seed rate was significantly differed from the higher seed rate. However, in row planting method almost in all seed rate did not show significance difference. In broadcasting, the higher seed rate gives the shortest plant height because of the competition among the plant population per the unit area (sunlight, water, and nutrient). But, in the row planting method relatively the plant population obtained optimum sunlight except the remained resource shared equally. Therefore, there was not shown a statistically significance difference between the seed rate of row planting method. In agreement, with Bekalu and Arega (2016) reported that the longer plant height was score from 5kg ha^{-1} which is from the lower seed rate of their study. However, Abraham et al. (2014) found that the shortest plants were obtained from the seeding rate of 2.5 kg ha-1 whereas the tallest plants were obtained from the seeding rate of 25 kg ha^{-1}.

Numbers of tillering were influenced by the lower seed rat. The higher numbers of tillering were counted from the rate of 2.5 to 7.5kg/ha of broadcasting and 2.5 to 5kg/ha row planting, 6-7 number of tillers and 6-7.5 number of tillers, respectively. Whereas, the minimum number of tillers were counted from the maximum seed rate 15 to 25kg/ha for both planting methods. In general, all the above traits days to maturity, plant height and number of tillers highly affected by the lower seed rate. This might be due to lower population per growing area get the enough amounts of resources. This study concurrently agrees with report of Abraham et al. (2014) the higher mean numbers of fertile tillers were obtained at the seed rate of 2.5 kg ha^{-1} as compared to other seed rates.

This study shows that the higher yield was obtained from the seed rate of 7.5kg/ha (2350kg/ha) in row planting. However, there was not statistical significance difference among the following seed rates 2.5, 5, 7.5,10,15 and 25kg/ha in row planting method. In other way, for the broadcasting method the higher grain yield was at rate of 15kg/ha (2132kg/ha) following the seed rate of 25, 5, 20kg/ha. Yet the broadcasting did not show a statistical significance difference between the tested rates and row planting except for row planting rate of 7.5kg/ha. The planting methods were not shown a statistical significance difference; in agreement with Fufa et al. (2001) they reported that drilling in rows did not show significant grain yield advantage over the broadcasting method. However, Bekalu and Tenaw (2015) reported grain yield increases in row planting over the broadcasting type. This finding indicated that tef grain yield can increase with seed rate of 7.5 to 15kg/ha in row planting. Moreover, in areas which are row planting is inapplicable (stony, highly sloppy and very wet black soil) and limitation of precise tef planting machine, productivity of tef increases using a broadcasting with rate of 15kg/ha. The investigation of present study implies that the production tef depends on the seed rate level than the planting methods. In fact, optimum populations mean it does not show the planting method; it is only shows the number of tef plants per unit area. Therefore, use of 7.5 to 15kg/ha and 15kg/ha, row planting and broadcasting respectively enhance the production of tef.

In general, the lower seed rate increase the tef grain yield in contrast with Abraham et al (2014); Sakatu and Adane (2017) reported that the highest grain yield was obtained in response to establishing at the highest seed rate of 25kg ha^{-1}-20kg ha^{-1}.Where as, in agreement to the finding of Sate and Tafese (2016) the 10kg ha^{-1} was recorded the highest grain yield than from the exceeded seed rate.

Table 3. had a result of individual location and year. Hatsebo (L/M) with clay loam in the first year of experiment obtained the higher yield from the rate of 7.5kg/ha (2482kg/ha) while in the second year a seed rate of 10kg/ha recorded the higher yield (2822kg/ha) in row planting. Therefore, tef productivity increase using a seed rate of 7.5kg/ha to 10kg/ha in areas like hatsebo (clay loam soil).Whereas, at Naederadet(silt loam) in first year the higher yield was obtained from 25kg/ha (2049kg/ha) in row planting while at the second year also from the rate of 5kg/ha(2834kg/ha).However, these seed rate were not statistical significance difference with the minimum 2.5kg/ha of row planting up to 25kg/ha. Then, we can select a seed rate applicable for the small scale framers ranging from 10 to 15kg/ha.

Table 3. The mean grain yield performance for each location and year

Planting methods and seed rates	Hatsebo		N/Adet		Combined Grain yield(kg/ha)
	2012G.C	2013G.C	2012G.C	2013G.C	
Broad cast at 2.5 seed rate	1918.0bcde	2342.0cde	1457.7bcd	2284.3cd	2000.50cd
Broad cast at 5 kg seed rate	2243.1abc	2492.7abc	1083.3d	2622.0abc	2110.28bcd
Broad cast at 7.5 kg seed rate	2092.6abc	2420.3bcd	1599.0bc	2313.0cd	2106.24bcd
Broad cast at 10 kg seed rate	2333.6ab	1993.0e	1474.7bcd	2339.0cd	2035.08cd
Broad cast at 15 kg seed rate	1563.6de	2738.3ab	1708.3abc	2521.7abc	2132.99bcd
Broad cast at 20 kg seed rate	2239.4abc	2432.0bc	1307.7cd	2431.3bc	2102.59bcd
Broad cast at 25 kg seed rate	2094.4abc	2424.7bcd	1533.7bc	2452.0abc	2126.19bcd
Row planting at 2.5 kg seed rate	2046.3	2600.0abc	1619.7bc	2450.7abc	2179.17abc
Row planting at 5 kg seed rate	1515.6e	2698.7abc	1709.7abc	2834.7a	2189.66abc
Row planting at 7.5 kg seed rate	2482.7a	2616.0abc	1552.3bc	2749.3ab	2350.10a
Row planting at 10 kg seed rate	1818.5cde	2822.3a	1675.7abc	2822.3ab	2284.71ab
Row planting at 15 kg seed rate	2223.2abc	2522.7abc	1382.7bcd	2522.7abc	2162.81abc
Row planting at 20 kg seed rate	1987.3bcd	2067.7de	1729.0ab	2010.3d	1948.58d
Row planting at 25 kg seed rate	2302.4ab	2518.0abc	2049.0a	2295.3cd	2291.18ab
Grand Mean	2061.50	2477.73	1563.02	2474.90	2144.29
CV	12.79	8.618	15.4637	9.637	11.31
LSD	754.55	358.38	405.66	400.33	196.39
R-square	0.637387	0.66503	0.57033	0.602530	0.8390
Location x treatments					0.0733ns
treatment(0.05)	0.0036**	0.0028**	0.0166*	0.013*	0.0042**

**=highly significance,*=significance

Considering the condition of planting time, the moisture content and leveling of the farm land is very essential for tef planting. Tef must be planted in fine soil level. Therefore, at high/enough to medium moisture content and clay loam soil type, it is better to use a seed rate of 7.5 to 10kg ha^{-1} with row planting spaced 0.2m. Whereas, in limited moisture content and silt loam soil type increasing the seed rate 10 to 15kg ha^{-1}using a space of 0.2m is well appropriate for increment of tef production and productivity in the study areas and similar agro-ecology with tested locations. Increasing the seed rate more than 10kg ha^{-1} can help the crop establishment at field when the moisture content and appropriate tef planter is limited.

Conclusions and Recommendations

Tef traits are highly influenced by the seed rate levels rather than the planting methods i.e broadcasting and row planting. This indicates that planting method did not shown a statistically significance difference for yield and yield component of tef. The present study indicated that the lower seed rate increases planting height, number of productive tillers and the grain yield. Therefore, the productivity of tef can increase using both planting methods depending on farm condition; level of the farm, soil type and agro-ecology. The grain yield of tef enhanced with optimum seed rate of 7.5kg/ha to 15kg/ha in row planting, while in the broadcasting 15kg/ha. A seed rate ranged from 7.5 to10kg/ha with row planting spaced 0.2m at clay soil is appropriate. Whereas, for red soil(silt loam) N/adet(TabiaSelam) increasing seed rate 10 to 15kg/ha is an optimum for grain yield increment. In areas a row planting is not applicable 15kg/ha a seed rate of broadcasting optimizes the population per unit area. To enhance the production of tef in the region as well as in nation understanding the soil moisture content at planting, soil texture, soil compaction level and time of planting, precise tef planter machine development needed.

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1.8. Evaluating of Tef Genotypes for Grain Yield and Agronomic Performance in North Western Tigray, Ethiopia

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Abstract

Tef is becoming the most preferred crop both for consumption and market value in Ethiopia. However, its production and productivity is still very low due to different problems. The aim study was to select best adapted and good agronomic performance variety/ies. The trial was carried out during 2017 and 2018 cropping seasons on station with twenty-eight tef varieties including standard and local check. Alpha lattice experimental design with three (3) replications was used on plot size of 2m x 2m. The data was analyzed using Genestat software and means were separated using Duncan mulple range test (DMRT). The combined two years data analysis showed that varieties varied significantly for most studied traits at ($P \leq 0.01$ and ($P \leq 0.05$). Based on the result, variety 'Niguse' was higher yielding variety followed by the 'Tesfa' and 'Guduru' with the values of 1880.0, 1769.0 and 1692.0 kg ha^{-1}, respectively. Greater than 20% yield increment was observed on standard check (Quncho) and local check (22.65%) respectively. The varieties 'Guduru', 'Wollenkomi' and 'Magna' were found to be having high biomass with the values of 9599.0, 9166.0 and 9139.0 kg ha-1, respectively. Therefore, these varieties helpful to enhance the tef productivity and production in the study area and similar agro ecologies.

Keywords: Adaptation, Grain Yield, Stable and Variety,

Introduction

Tef (*Eragrostis tef* (Zucc.) Totter) is an allotetra ploid species with chromosome number (2n =4x = 40) plant, C4 self-pollinated, annual, warm season cereal crop; believed to have originated in Ethiopia and have been domesticated and used throughout the world due to its excellent nutritional value as grains for human consumption and as forage for livestock (Miller 2010). The has great genetic diversity (Ayalew et al. 2011 and Ayalneh et al. 2012), thus leading to increased opportunity to develop cultivars that could be suitably adapted to any country that would invest in tef production.

Based on report of Vavilov (1951) Ethiopia is not only the origin of tef, but also the center of diversity where it contributes great role towards sustaining food security. Five major cereals namely Tef, wheat, maize, sorghum and barley are the core of Ethiopia's agriculture and food economy, accounting for about three-quarters of total area cultivated (Alemayehu et al. 2011). Out of 10.23 million hectares of land occupied by cereals, tef the single dominant cereal took up 3.023 hectares annually and the production is about 52.8 million quintals (CSA 2018).

Research has also shown that tef is free of gluten (Miller 2010) and the grain of tef in Ethiopia country is mainly adopted for food after baking the ground flour into pancake-like soft and sour bread, "injera" which forms the major component of the most favorite national traditional dish. It is also consumed in the form of porridge, and somewhat fermented or un-fermented non-raised breads ("*kita*" and "*anebabero*"), native beer, "*talla*", and more alcoholic cottage liquor, "*katikalla*" or "*arakie*" (Assefa et al 2015).

The development of tef variety for wider adaptable is a major interest and a challenging condition for breeders (Kassa et al. 2013). This challenge is due to the genotype by environment interaction (GEI) which causes limiting for identifying superior genotypes. GEI is the relative performance of genotypes varies from one environment to others (Yali et al. 2004).

Studying, interactions between genotype and environment have an important bearing on the breeding of better varieties (Allard and Bradshaw 1964). Thus, evaluation of genotypes for stability of performance under varying environmental conditions for yield has become an essential part of any breeding programe since it can help in identifying traits and environments for better cultivar selection. So, development of improved tef varieties with high yield and yield components for different environments is one of the exciting research leads to successful evaluation of stable genotype, which could be used for general cultivation.

Despite the aforementioned importance and large area, coverage, good prioritize, national productivity of tef in Ethiopia is low (1.73 t ha^{-1}) and incomparable with other major cereal crops like sorghum (2.73 t ha^{-1}), wheat (2.5 t ha^{-1}) and 3.9 t ha^{-1} (maize) (CSA 2018). This reduction of tef crop productivity could be resulted from a complex interaction among the environment, crop genetics, and management, biotic and abiotic stress that could occur across tef growing areas. Ermias et al (2007) also reported, low soil fertility, weeds, and erratic rainfall distribution and drought particularly in the areas of low altitude, lack of high yielding cultivars and water-logging. Other factors contributing to its low in productivity are lodging, method of planting and fertilizer application; the combined effect of those factors result up to 22% reduction in grain and straw yield (Hailu and Seyfu 2001).

Hence, a lot is expected from tef breeders and all stakeholders to improve the productivity and minimize the yield gap with other major cereals and it is possible to increase its grain-yield up to 4 t/ha by using improved varieties and good management practices under non-lodging condition (Hailu and Seyfu 2001). The national and regional research institutions released many tef varieties adaptable to a wide range of environment of them specifically in the current testing site Medebay zana district, quncho and kora are under production. Howsoever, these varieties cannot fulfill the yield gap. Therefore, evaluating tef varieties on yield and adaptability is important to minimize the yield gap from the existing tef varieties. The purpose of the study was to evaluate stable and high yielding tef varieties for late maturing types

Materials and Methods

The study was conducted at, Selekleka research site, in Tigray Regional State in Northern Ethiopia in the 2017 and 2018 cropping seasons. The experimental site is situated at the latitude of 14°6′43″ N, longitude of 38°27′50″E, and at the altitude of 1951 m above sea level . The mean annual rainfall is 680 mm. The soil textural class is clay loam with pH of 7.2. The experimental material comprised of twenty eight nationally released varieties obtained from national tef research institute based at Deberziet and one standard check and one local check include in the study. . The genotypes were planted during the main rainy season of 2017 and 2018 in a well prepared soil under alpha lattice design with three replications. Row planting with spacing of 0.2m between rows was used on a plot size of 2m x 2m with a gross area of 4 m^2. Ten rows of tef per plot were planted and the middle eight rows were used for data collection and analysis. Spacing of 1m and 1.5m between plot and block respectively was used. Planting was done in row by drilling at seed rate of 15kg ha^{-1} and fertilizer rate of 100 kg ha^{-1} Urea and 100 kg ha^{-1} DAP. Half of the Urea was applied after 18-25 days after sowing and the rest half was applied at mid tillering stage nearly 30-45 days after sowing (top-dressing). Standard cultural practices were followed from sowing till harvesting during the entire cropping season. Data was recorded based on plot and individual plant basis for phonological, yield and yield related. Lodging scale (1-5) also recorded which is 1 very resistant for lodging while 5 is very susceptible for lodging. All the data recorded were subjected to the analysis of variance of techniques using Genestat software packages (Genestat 18th edition) where in means were compared using Duncan multiple rage test (DMRT) at 5% levels of probability.

Results and Discussion

Agronomic performance of tef varieties

The combined analysis of variance was showed presence of significant difference among the tested varieties for most of the phonological, growth, yield and yield related characters (Table 1). This indicates there was variance between the tef varieties on these traits for the testing site.

Date of 50% heading: there was a significance differences between the varieties for days to 50% heading. The presence of highly significant phenotypic variability among the 30 tef varieties for this trait, indicated that there is a possibility to exploit the variability on days to heading and select optimum heading tef variety. Supportive results to the present findings were also reported by Ayalneh et al. (2012) and Habte et al. (2015), who also found significant genotype difference in important yield related traits. Early heading was recorded by variety 'Holetta Key' followed by 'Keye'. However, variety 'Dagim' exerts late heading followed by 'kora'. while selecting varieties for early maturing, considering early heading varieties could be imperative. Fentie et al. (2012) and Plaza-Wuthrich et al. (2014) also reported significant difference among the tested varieties for date of heading.

Days to maturity: there was a significant difference observed among the tested variety for date of maturity across the seasons. Identification of genotypes of different days to flowering and maturity is useful in adjusting sowing time in order to avoid adverse climatic conditions (Olesen et al. 2012). Moreover, planting tef genotype with the appropriate growing period allows effective use of seasonal rainfall. Similar result was also reported by Fentie et al. (2012).

Table1. Combined mean yield and yield related traits performance of released tef varieties at, Medebay zana, Tigray in 2017 and 2018

S.N	Pedigree and Varieties	DH	DM	PL(cm)	PHt(cm)	BY kg/ha	GY kg ha $^{-1}$	HI%	Lodging(1-5)
1	DZ-01-196(Asgori)	53.33	98	39.4	103.19	8093	1269	16	2.8
2	DZ-01-354(Enatit)	57.83	101.17	41.47	104.79	7832	1223	16	2.7
3	DZ-01-196(Magna)	58.5	100.5	40.82	105.17	9139	1414	16	3.3
4	DZ-01-787(Wellenkomi)	59.33	99.67	43.27	104.61	9166	1299	15	2.5
5	DZ-cr-44(Menagesha)	57.33	99	38	103.07	8790	1351	17	2.8
6	DZ-cr-82(Melko)	57.33	99.67	39.57	101.52	8126	1390	18	2.7
7	DZ-cr-255(Gibe)	57.33	101	41.3	104.56	7189	1175	17	2.8
8	DZ-cr-358(Ziquala)	57	100.5	40	106.86	8073	1427	18	3.3
9	DZ-01-974(Dukem)	58.5	99.67	45.7	112.16	9047	1582	18	2.8
10	DZ-01-1281(Gerado)	57	98.17	41.27	104.84	7778	1116	15	3.3
11	DZ-01-1285(Keye)	53	98.83	43.5	105.38	8215	1377	17	3.0
12	DZ-01-1681(KEyTena)	54.5	98.5	39.9	99.28	7529	1166	16	3.2
13	DZ-01-899(Gimbichu)	57.83	100.5	41.9	104.67	8447	1151	15	3.2
14	DZ-01-2675(Dega Tef)	55	99.67	46.17	112.95	7743	982	14	2.8
15	DZ-cr-387 RIL 355 Quncho	61.67	98.67	45.3	118.93	9073	1517	19	3.2
16	DZ-01-2053(Holetta Key)	52.17	98.33	35.8	88.29	6609	1075	16	3.8
17	DZ-01-1278(Ambo Toke)	57.17	100.83	41.77	103.53	7426	972	14	2.8
18	DZ-01-2054(Gola)	56.17	98.67	44.83	107.47	8256	1397	18	2.7
19	DZ-01-1821(Zobel)	54.83	100	42.73	101.83	7459	1013	15	3.5
20	DZ-01-1868(Yilmana)	57.17	100.33	41.73	102.14	6365	1068	20	2.7
21	DZ-01-2423(Dima)	53.83	100.67	43.47	108.03	7949	1334	17	2.8
22	DZ-01-3186(Etsub)	58.67	100.83	43.7	111.51	8722	1377	17	3.2
23	DZ-01-1880(Guduru)	56.5	100.83	46.43	110.38	9599	1692	19	3.2
24	PGRC/E 205396(Ajora)	55.5	100.17	41.9	105.96	7880	1451	19	3.5
25	Local Check	56.33	99.67	37.77	103.29	6884	1454	27	2.5
26	Kora	61.33	100.67	45.8	115.48	8729	1661	20	2.7
27	Dagim	60.17	98.83	36.93	108.13	8329	1419	18	2.3
28	Tesfa	59.67	97.17	42	105.52	7303	1769	29	2.5
29	Flagote	54.17	98.83	40.13	102.28	7817	1314	18	2.7
30	Dz-cr-429(RIL#125) Nigusse	57	100.5	41.93	102.19	8648	1880	22	2.7
	Grand Mean	56.87	99.66	41.82	105.6	8074	1344	18	2.9
	CV	4.5	1.7	7.5	5.1	13	14.8	18	17.3
LSD	Genotype	2.894**	1.92**	3.59**	6.12**	1199.4*	227.1**	0.04**	0.58**
	Year	0.75**	0.25**	0.93**	1.58ns	309.7**	58.6**	0.01**	0.15**
	Gene * Year (Envit)	4.092**	2.71**	5.08**	8.66**	1696.2**	321.2**	0.05**	0.82*

DH- Days to 50% heading, DM- Days to 75% physiological maturity, PHt- plant height, PL-panicle length, GY- grain yield, BY- biomass yield, HI-harvest index in percentage

Considering this character for variety selection is very critical in order to select early maturing varieties for different agro ecologies. Accordingly, variety ‘Tesfa’ followed by ‘Asgori’ and’ Holleta’ key was early maturing as compared to local check and other varieties.

Plant height: plant height and panicle length (PL) of tef are important features that positively contribute to yield on the one hand. Among the tested varieties, Quncho shows the longest height followed by kora 118.9cm and 115.5 whereas variety ‘Holleta key’ and ‘Key Tena’ exerted the shortest height. Considering this character for variety evaluation is very crucial as it help for selecting varieties that can able to with stand lodging problems.

Panicle length: the present finding shows a significant difference was observed at ($P \leq 0.05$) among the tested varieties for panicle length, which was ranged from 35.8 (Holleta key) to 46.18(Guduru). Accordingly, variety Guduru shows maximum panicle length whereas variety Holleta key shows minimum panicle length. Late set varieties were produced longer panicles i.e Dega tef and Guduru and this study also confirmed with previous studies which indicated late maturing varieties have long plant and panicle height. Many studies have indicated the presence of substantial variation among tef genotypes for different traits of tef. Different authors Ayalneh et al. (2012) and Habte et al. (2011) reported that highly significant genotype variation for days maturity, plant height, panicle length, shoot biomass and grain yield, harvest index, lodging index and thousand seed weight.

Harvest index (HI %): a significant difference was depicted among the varieties across the years for the character HI which was ranged from 14 to 29 %. Maximum HI was exerted by variety Tesfa followed by local check due to their heavy seed weight and high number of seeds per panicle. Low HI was revealed by variety Dega tef (Table 1). Harvest index is important yield parameters in various grain crops including tef. The more harvest index showed more grain yield over biological yield and vice versa.

Grain yield (GY): evaluated tef genotypes shows that highly statistically significant difference ($p \leq 0.01$) for grain yield. (Table 1) Grain yield variation was ranged from 9.72 to 18.80 qt/ha with the mean value of 13.44qt/ha. The highest grain yield (18.80) and (17.69 qt/ha) was recorded for 'Niguse' and ' Tesfa' respectively. But, low yield of 9.72 qt/ha was obtained from variety Ambo Toke (Table 1). This variety had yield advantage of 20% on the standard check (Quncho) and 22.65% over the local check. Variation in yield shows a diverse genetic background of genotypes studied under these conditions. The possible reasons for the observed difference could be variation in their genetic makeup and seasonal variation. With this as (Dagnachew et al (2014) finding indicates the varietal stability could be challenged not only due to the change in the test environment but also due to change in growing season per environment.

Biomass yield (kg ha^{-1}): total biomass production (kg ha^{-1}) was significantly different among the genotypes, years and genotype by year interactions. The variety 'Guduru' superseded all the genotypes with highest biomass yield of 9599.0 kg ha-1. It was followed by the varieties 'Wellenkomi' and 'Quncho' with biomass yield of 9166.0 and 9073.0 kg ha $^{-1}$, respectively. The genotype 'Yilmana' showed poor performance in this experiment and producing only 6365.0 kg ha^{-1}. This also in line with the finding of (Daniel et al 2016) who studied with released fourteen released tef varieties. It was further observed that the variety 'Niguse' remained superior in term of both grain and biomass yield as well as in other important yield components (Table 1).As Kebebw et al. (2011) noted that, presence of genotype by environment interaction for most of the traits is in line with the current focal strategic direction of the tef breeding program (shift from wide to specific adaptation). This is the variance of tef varieties in genetic potential for production biomass.

Environmental effect on tef yield and yield related traits

The test environments (testing years) has showed substantial effects on all the traits studied except plant height for days to heading, days to physiological maturity, grain yield, biomass yield, panicle length etc.) indicating that the years were adequately diverse to reveal the performance of the tef genotypes (Habte et al. 2015). Substantial genotype by environment interactions for all traits evaluated indicating that the test genotypes had differential performance at diverse years due different in amount and distribution of received rain fall, temperature and humidity (weather variability).

Depending up on the magnitude of the interactions or the differential genotypic response to environments, the varietal ranking can differ greatly across environments (seasons). The performance of a genotype is not necessarily under diverse agro- ecological zones. Therefore, crop performance depends on the genotype, the environment in which it grows and the interaction between them. According to Eberhart and Russell (1966) information on the interaction of genotypes with environment is crucial in developing new cultivars for production in diverse environments. Such information guides the breeder in choice of selection methods and to test locations for optimal character expression. ANOVA result showed significant difference among the genotypes in genotype by environment interaction and it need further stability analysis to test the repeatability performance of the winner genotypes across the environment

Mean performance and stability analysis

Ranking of thirty tef genotypes based on mean yield performance and stability is presented in Figure 1. The single arrow line passing through the biplot origin and the average environment indicated by the small circle is the average environments coordinate (AEC) axis, which is defined by the average PC1 and PC2 scores of all environments (Yan and Kang 2003). This line points towards higher mean yield across environments. As Yan et al (2002) reported that AEC abscissa has a one directional arrow which is important for approximating the mean yield performance of the genotypes. G30 was the highest mean yield with less stability, while genotypes G28, G26, and G23 were the next high yielding genotypes relatively stable. However, the genotypes which yielded bellow average mean yield were G14 ,G19 and G20 (Figure 1). Either direction away from the biplot origin, on this axis, indicates greater genotype by environment interaction and poor stability or vice versa (Kaya et al. 2006). A genotype which has shorter absolute length of projection in either of the two directions of AEC ordinate (located closer to AEC abscissa), represents a smaller tendency of GEI, which means it is the most stable genotype across different environments or vice versa. Genotypes G1, and G3 were low yielding comparatively stable (Figure 1).

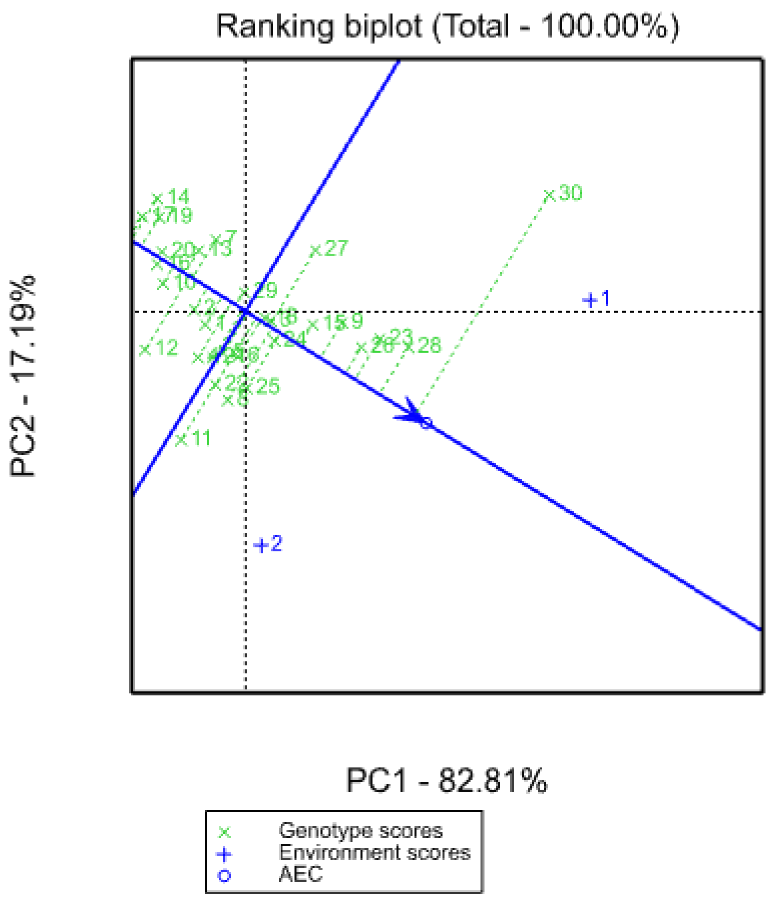

Figure 2: mean yield performance of genotypes across average environment coordination(AEC)

Conclusion and Recommendation

Conclusion

Based on the analysis of variance, the varieties at the given location in both years exhibited significant variation for most traits studied except plant height, which showed non-significant variation at ($p \leq 0.05$) across years and results of most studied traits indicated there is considerable amount of diversity among the tested varities which could be manipulated for further improvement in tef breeding and besides, this high genotype by environment interaction results on many of the agronomically important traits evaluated in the present study indicates that breeding for specifically adaptable varieties would be important and wise growing of varieties based on season metrological prediction even in a single environment is crucial now a days. 'Niguse' variety gave highest grain yield (18.80 qt/ha) relative to the rest varieties in both years' at the given district followed by 'Tesfa' (17.89 qt/ha) yield performance. Therefore, cultivations of Niguse and Tesfa varieites enhcnce the productivity of tef in this study area and similar agro-ecologies.

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1.9. On-Farm Screening of Insecticides Against Cotton Mealybug (*Phenacoccus solenopsis*Tinsley*)* Infestation in Western Tigray, Northern Ethiopia

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Abstract

Production of sesame in Ethiopia is very crucial in many aspects, but there are many biotic and abiotic stresses reducing the productivity. Nowadays, Cotton mealybug *Phenacoccus solenopsis* Tinsley, has been found as a newly emerging and invasive insect pest of sesame in North Western Ethiopia. The objective of the study was to identify effective insecticides against cotton mealybug. The experiment was conducted at farmers' field in Kafta-Humera during 2018 cropping season in two farmers' fields. The experiment consisted of 13 treatments using Randomized Complete Block Design (RCBD). The highest incidence (100%) of the insect pest at 2 days after spray (2DAS) was recorded in the plots where Chlorotak, High Way and Profit insecticides applications. Lower incidence (32.5%) was recorded in Diaznon applied plots. The lowest incidence (23.33%) at 4DAS (11.67%) at 6DAS; and highest incidence (76.67%) at 4DAS and (68.33%) at 6DAS were recorded from Diaznon and the control respectively. The highest cotton mealybug mean incidence (94.49%) before insectide sprayed (PS) finally deceased to (31.28%) at 6DAS of the insecticides was observed. The mean severity of all the insecticides 2.8 observed before insecticide sprayed finaly decreased to 1.3 at 6DAS of the insecticides and Diaznon was the most effective insecticide with zero severity at 6DAS. Finally, farmers in these areas are advised to use Diaznon for controling cotton mealybug in sesame fields.

Key Words: Diaznon, Insecticide, Mealybug, Sesame, Severity

Introduction

The world sesame area coverage and production were 9983165 ha and 5,531,948 tons respectively in 2017. Tanzanya, Myanmar, India, Sudan, Nigeria, China and Ethiopia are the major sesame producers in the world in that order (FAOSTAT 2017). Sesame (*Sesamum indicum*L.), the ancient crop known and used by man, has been planted for over 7,500 years in Asia and Africa even in very poor growing conditions and currently it is widely grown as an oilseed crop in around 76 countries (Langham et al. 2010). In Ethiopia, sesame is the second largest agricultural commodity for the source of foreign currency and good source of cooking oil through local extraction. Despite its importance as source of cooking oil and foreign currency earning, sesame productivity is low especially in dry land area like in Tigray (Teame et al. 2017).

Production of sesame in the country is very crucial in many aspects, but there are many hurdles for its production and productivity, such as pest infestation, seasonal delay, low yielding, post-harvest loss, poor storage facility, difference in capsule maturity, shattering reference etc. Among the many insect pests affecting sesame production worldwide sesame seed bug ('*Setayito'*), sesame webworm (*Antigastra catalaunalis*), termites, gall midge (*Asphondilia sesami*), green vegetable bug (*Nezara viridula*), African bollworm (*Helicoverpa armiger*), grasshoppers, aphids, jassids, whitefly, field crickets have been recorded in Ethiopia (Geremew et al. 2012). Insect pests such as sesame webworm *(Antigastra catalaunalis)*, sesame seed bug (*Elasmolomus sordidus*), gall midge (*Asphondilia sesami*) are the most important insects that affect production of sesame during its different growing stages (Zenawi et al. 2016). In the sesame growing parts of Tigray sesame seed bug (*Elasmolomus sordidus*) caused a weight loss of 94.7% at 11th days after stored in opened sacks (Berhe et al. 2008) is the major insect pest of sesame. However, nowadays, cotton mealybug *(Phenacoccus solenopsis* Tinsley), has been found as a newly emerging and invasive insect pest of sesame especially in the North western sesame growing areas of the country.

The pest was first time reported in 1991 as a severe pest from Texas, America which later on spread throughout the world. During the first decade of 21st century mealybugs emerged as the most devastating pest of agricultural crops. *P. solenopsis*is a polyphagous insect feeding on about 200 plants but it causes economic damage mainly to cotton, brinjal, okra, tomato, sesame, sunflower and China rose (Arif et al. 2012). Mealybugs feed on all parts of plants, particularly on leaves and branches that join stems. According to Hodgson et al. (Hodgson et al. 2008), there is a striking difference in the mealybug’s distribution on the plant between southwestern USA and Mexico populations and the Indian subcontinent populations. That is, “in the hot, dry conditions of the Mexican and Californian summer, *P. solenopsis* occurs mainly on roots or on the underside of foliage and stems very close to the soil, whereas in India and Pakistan it is found almost exclusively on the upper parts of the plant, well above soil level. This difference in the distribution on the plant maybe due to differences in humidity, which is much higher in India and Pakistan (Hodgson et al. 2008). Same is true in Ethiopia, the pest occurs on the upper parts of the plant. But in the hot dry period (*Hagay*) the pest has observed in the roots of perennial weeds mainly like *lactucaserriola* 'Demaito' and *Sidacordifolia* '*Ezni Tel*' (Personal observation); Perhaps this could be a mechanism to escape the harsh condition.The crawlers disperse from the ovisac by way of walking, wind, or ants. The nymphs feed and develop into adults in approximately 30 days. Nagrare (2014) stated that reduction in cotton yield because of cotton mrealy bug was estimated to be 15.7% and 52.7% for Grade 1 and Grade 4 infestation levels, correspondingly. Gebregergis (2018) reported that 100% yield loss in sesame has been observed in respect to grade 4.

Because of this insect is disastrous several researches have been done to control it. However, the use of conventional insecticides to control Cotton Mealybug has been proved unsatisfactory and is hard as the result of the cryptic behavior of mealybugs, clumped spatial distribution pattern and their typical waxy body cover (Arif et al. 2009); (Joshi et al. 2010). Furthermore, because of its high reproductive capacities and multiple generations annually it is potentially capable of becoming resistant to different insecticides on consistent applications. Cotton mealybug has introduced via mango seedlings to '*Kafta-Humera'* in 2012. According to the Western Tigray Bureau of Agriculture(unpublished data) the pest has introduced from Awash area through mango seedlings. Through different management practices (destruction of infested plants, burning, burying and chemical spraying) it was successfully kept from expansion and spread but in 2016 cropping season (*Kiremti*) an eruption of mealy bug invasion was observed in some sesame fields of *Kafta-Humera*. Hence, the purpose of this study was to evaluate the efficacy of different insecticides against cotton mealy bug in the sesame fields.

Materials and Methods

Description of the study area

A field experiment was conducted to investigate the efficacy of different insecticides against mealybug at farmers' field in *Kafta-Humera*, Western Tigray (Fig1). The agro-ecology of the location is described as hot to warm semiarid plain with mean temperature of 29°c, annual mean rainfall of 581.2 mm (which ranges from 380 to 870 mm), verti soil with pH value of 8.4 and husbandry variations.

Experimental design and material

Assessment of mealybug was conducted starting from the seedling stage in 2018 cropping season. During this season an infested area was selected from the sesame fields of *Kafta-Humera* woreda. Two farmers' plots were selected and the design was formed after selecting the infested areas. The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications in the two locations of farmers' field. The path between blocks and plots were 2 m each and about 5m*2m area was delineated for each treatments/insecticides. A total of 13 treatments (12 insecticides and a control) were evaluated including a control check (non-treated) and all insecticides were applied at the manufacturers' rate using hand knapsack.

Table 1. List of insecticides their active ingredients and mode of action

S No	Insecticide	Active ingredient	Mode of action
1	Best field	Unknown	Unknown
2	Chlorotak	Chlooropyrifos Ethyl	Contact
3	Closer	Sulfocslor	Systemic
4	Confidence	Imidacloprid	Systemic
5	Control	Control	Control
6	Curador	Profonfos, Lufenuron	Contact and systemic
7	Deltarin	Deltamethrin	Contact
8	Diamog	Dimethoate	Systemic
9	Diazinon	Diazinon	Contact
10	High Way	Lamdaculothrin	Systemic
11	Perfecto	Imidacloprid, Lamdacylothrin	Contact and systemic
12	Pritacet	Acetamiprid	Contact and systemic
13	Profit	Profonfos	Contact and systemic

Data collection

Incidence and severity of the insect was collected before the application of the insecticides. Incidence (INC %): was recorded in plot wise by counting total infested plants in the plot for consecutive 6 days in two days interval starting from the application date of the insecticides. Incidence was calculated using the formula:

$$\text{Incidence}=\frac{\text{Number of infested plants}}{\text{Total plants in the plot}}\text{X 100}$$

- ✓ Severity: was also recorded from five randomly selected and tagged plants for 6 days in two days interval starting from the application date of the insecticides. It was scored on 1-4 scale based on presence of the mealybugs in the sesame plants and categorized as the below categories:

a. Scale 1– Scattered appearance of few mealybugs on the plant (<25% of the plat is covered by mealybugs)
b. Scale 2– Severe infestation of mealybugs on any one branch or on less than half of the plant (25-49% of the plat is covered by mealybugs)
c. Scale 3– Severe infestation of mealybugs on more than one branch or half portion of the plant (50-75% of the plat is covered by mealybugs)
d. Scale 4– Severe infestation of mealybugs on the whole plant (>75% of the plat is covered by mealybugs)

- ✓ Efficacy (%): was also computed as the percentage of the efficacy of the insecticides using the incidence of the cotton mealy bug at final count (6DAS) subtracted from the incidence at pre insecticide spray using the formula:

Efficacy (%)= (Incidence at pre spray - Incidence after spray)*100

Data analysis

The collected incidence and severity data of the experimental plots was analyzed using computer statistical software Genstat-18th. A combined and individual incidence and severity from the different experimental plots (in different days intervals) were analyzed. Means were compared using Duncan's Multiple Range Test (DMRT), at 0.01 probability level.

Results and Discussion

Incidence of cotton mealybug across experimental plots

Both experimental plots (Farm-1 and farm-2) were highly infested by cotton mealybug before the insecticides were applied. The pre-spray incidence level of farm-1 ranged from 73.33-100% while the pre-spray incidence level of farm-2 was 100% in all experimental plots. There was a statistical significant difference in the incidence of the cotton mealy bug among the insecticides in farm-2 while there was no statistical significance difference in farm-1 at 6 DAS (Table 1).

(Sahito and Abro 2012) also reported that there was significant difference from location to location and even among adjacent farmlands and this may be mainly associated with the means/way of the insect pest expansion.

Table 2. Incidence of the Mealybug at pre-spray (PS) and 6 days after spray (6DAS) across the farms in2018 at Kafta Humera, Ethiopia.

	Farm-1		Farm-2	
Chemicals	Inc PS (%)	Inc 6DAS (%)	Inc PS (%)	Inc 6DAS (%)
Best field	86.67	23.33	100	53.33
Chlorotak	100	26.67	100	23.33
Closer	73.33	13.33	100	30
Confidence	80	23.33	100	33.33
Control	100	50	100	86.67
Curador	83.33	43.33	100	20
Deltarin	73.33	33.33	100	46.67
Diamog	90	26.67	100	13.33
Diazinon	83.33	20	100	3.33
High way	100	53.33	100	23.33
Perfecto	93.33	23.33	100	33.33
Pritacet	93.33	26.67	100	23.33
Profit	100	40	100	20
Mean	88.97	31.02	100.00	31.54
CV (%)	4.2	71.4	0	50
LSD (5%)	6.32	ns	ns	26.47

CV= Coefficient of variation, LSD= Least significant difference

However, the mean incidences of the insect in both plots were similar with 31.02 % and 31.54 % in farm-1 and farm-2. The lowest incidence (3.33 %) of the cotton mealybug was recorded from Diazinon followed by Diamog (13.33%).In contrast to this, the highest incidence level (86.67%) was noted from the plot where no insecticide was applied (Control) followed by the insecticide named Best field (53.33 %). This difference in the level of incidence of the cotton mealybug may be because of the efficacy level of the given insecticides.

Incidence of cotton mealybug after insecticide spray

The combined mean of cotton mealybug incidence in the two experimental plots (farm-1 and farm-2) at two days after spray (2DAS), four days after spray (4DAS) and six days after spray (6DAS) is depicted in Table 3. There was statistical significant difference in the cotton mealybug incidence at pre-spray (PS) and post-spray among the insecticides at 2DAS, 4DAS, 6DAS and efficacy percentage.

Table 3. Combined mean (the two farms) of incidence of mealybug after insecticide spray in 2018, at Kafta humera, Ethiopia.

Chemicals	Inc PS (%)	Inc 2DAS(%)	Inc 4DAS(%)	Inc 6DAS(%)	Efficacy (%)
Best Field	93.33 ab	56.67 a	48.33 b	38.33 ab	60 ab
Chlorotak	100 b	56.67 a	35 ab	25 ab	75 b
Closer	86.67 a	43.33 a	33.33 ab	21.67 ab	75 b
Confidence	90 ab	61.67 ab	35 ab	28.33 ab	69 b
Curador	91.67 ab	58.33 a	35 ab	31.67 ab	65 ab
Deltarin	86.67 a	48.33 a	38.33 ab	40 b	54 ab
Diamog	95 ab	51.67 a	33.33 ab	20 ab	79 b
Diazinon	91.67 ab	32.5 a	23.33 a	11.67 a	86 b
High Way	100 b	61.67 abc	30 ab	38.33 ab	62 ab
Perfecto	96.67 ab	48.33 a	33.33 ab	28.33 ab	71 b
Pritacet	96.67 ab	55 a	35 ab	25 ab	74 b
Profit	100 b	52.5 a	28.33 ab	30 ab	70 b
Control	100 b	90 b	76.67 c	68.33 c	32 a
CV (%)	9	42.4	47.6	64.8	31.4
LSD (5%)	9.77	26.94	20.5	23.4	24.2

Inc= Incidence; Inc PS, Inc 2DAS, Inc 4DAS, Inc 6DAS: incidence at pre-spray, two days after spray, four days after spray and six days after spray respectively.

The lower incidence (32.5%) at 2DAS was recorded from Diaznon and obviously the highest incidence (90%) was recorded from the control followed by Confidence and High Way (61.67% each). Similar to the incidence at 2DAS, the lowest incidence (23.33%) at 4DAS (11.67%) at 6DAS; and highest incidence (76.67%) at 4DAS and (68.33%) at 6DAS were recorded from Diaznon and the control respectively. Furthermore, the highest efficacy of the insecticides was observed from Diaznon (86%) followed by Diamig (79%) which confirms these insecticides are relatively efficient and better than the other insecticides.(El-Zahi et al. 2016) reported that the incidence of cotton mealybug was decreased after the application of deltatrin, Chlorotak, confidence and others. These authors also reported that deltatrin (Deltamethrine) highly decreased the incidence of cotton mealybug from 99% at pre spray to 37.7% at 10 days after spray in cotton and this insecticide recorded better efficacy than Chlorotak, confidence and others. On the other hand (Patel et al. 2010b)reported that chlorotak showed efficacy than Profit and other insecticides. In contrast to this (Tanwar et al. 2011) reported that as Profit resulted better efficacy than, Confidence, Chlorotak and others. Generally, according to these different authors the efficacy of insecticides differs from country to country and from crop to crop which may because of environmental, management and other factors.

Generally, for easily visualization of the efficacy of the insecticides and incidence of the cotton mealybug after insecticde spray is depicted in figure 1. Regardless of the insecticides type the mean incidence of the cotton mealybug decrsead as the time interval from when the insecticides applied increased (Fig.1).

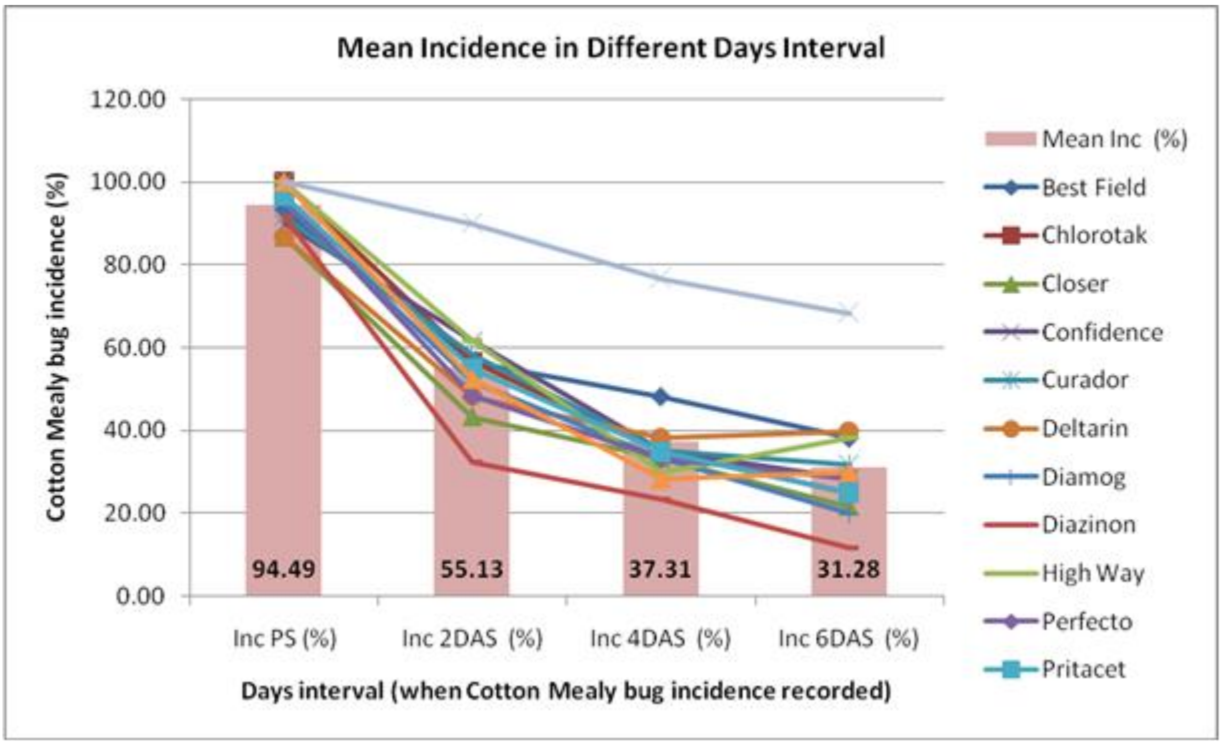

Figure 1. Mean incidence of cotton mealybug in different days interval after insecticide spray

This decrease in incidence of the insect is obviously because of most of the insecticides were effective. This is because incidence of cotton mealybug increases as time time has gone and ther are plants which the insect can feed (Hanchinal et al. 2011).This finding highly collaborates with the findings of (El-Zahi et al. 2016) who reported the incidence of cotton mealybug decreased regardless of the type of insecticides as the time interval from the time of application increased. Furthermore, the highest cotton mealybug mean incidence (94.49%) was obsrved before insectide sprayed (PS) finally deceased to (31.28%) at 6DAS of the insecticides applications.This indicates that most of the insecticides killed the cotton mealybug slowly and this may be because of the cotton mealybug tolerance to the different insecticides soon after spray. Similar to the incidencidece (in the different time intervals) treated by the different insecticides the incidence in the control also decreased to some extent and this is because of the plants in the control plot were highly damaged by the insect pest and the insect pest started either to emigrate to other non infested plots or died in that specific plots.

Severity of cotton mealybug after insecticides spray

The combined mean of cotton mealybug severity in the two experimental plots (farm-1 and farm-2) at two days after spray (2DAS), four days after spray (4DAS) and six days after spray (6DAS) is presented in Table 4. There was statistically significant difference in the cotton mealybug severity at both pre-spray (PS) and post-spray among the insecticides at 2DAS, 4DAS, 6DAS of the insecticides sprayed.

Table 4. Combined mean (two farms) of severity of mealybug after insecticide spray (scale 1-4).

Chemicals	Sev PS	Sev 2DAS	Sev 4DAS	Sev 6DAS
Best Field	3^{ab}	2^{b}	2^{ab}	2^{c}
Chlorotak	3^{b}	2^{ab}	1^{ab}	1^{abc}
Closer	2^{a}	1^{ab}	1^{ab}	1^{ab}
Confidence	3^{ab}	2^{b}	1^{ab}	1^{abc}
Curador	3^{ab}	2^{ab}	1^{ab}	1^{abc}
Deltarin	3^{ab}	2^{b}	2^{b}	2^{bc}
Diamog	3^{ab}	2^{ab}	1^{ab}	1^{a}
Diazinon	2^{a}	1^{a}	1^{a}	0^{a}
High Way	3^{ab}	2^{b}	1^{ab}	2^{bc}
Perfecto	3^{ab}	2^{ab}	1^{ab}	1^{abc}
Pritacet	3^{b}	2^{ab}	1^{ab}	1^{abc}
Profit	3^{ab}	2^{b}	1^{ab}	1^{abc}
Control	3^{ab}	3^{c}	3^{c}	3^{d}
CV (%)	22.4	37.3	50.5	61.1
LSD (5%)	0.8	0.9	0.8	0.9

Sev: Severity, Scale of 1, 2, 3, 4: population of mealybug covered the plant <25%, 25-49%, 50-75% and >75% respectively

The lowest severity (1for each) was recorded from Diaznon and Closer while the highest severity was observed in the control at 2DAS. At 4DAS and 6DAS the severity of most of the insecticides was decreased to one (1) except for the control, Best Field, and Deltarin with the severity of 3, 2, and 2 respectively. Exceptionally, a zero severity was observed in the insecticide Diaznon (Table 4 and Fig 2). (Tanwar et al. 2011) found that Profit showed better efficacy and lower severity than other different chemicals. (Dhawan et al. 2009) also reported that Confidence, Profit were effective insecticides among other different insecticides like Spirotetramate and chloropyriphos. Similarly, (Patel et al. 2010b); (Patel et al. 2010) also found that Confidence was relatively effective insecticide in controlling the cotton mealybug.

Similar to the incidence of the insecticides for easily visualization of the efficacy of the insecticides and to see the severity of the cotton mealybug after insecticide spray is depicted in Fig 2. Regardless of the insecticides type the mean severity of the cotton mealybug significantly decrsead as the time interval from when the insecticides applied increased (Fig. 2). This result is in accordance with the findings of (Mamoon et al. 2011) who stated that the total number of cotton mealybugs and severity significantly decreased by half (from 7.3 to 3.5 within 24 hrs. after insecticide application. The mean severity of all the insecticides 2.8 observed before insecticide sprayed finaly decreased to 1.3 at 6DAS of the insecticides. On the other hand the severity of the insecticides in the control plot was higher (3) and it remains similar in all time intervals (PS, 2DAS, 4DAS and 6DAS). This mean severity decreament indicates that most of the insecticides were effective in controlling cotton mealybug. To look on the severity of the individual insecticides Diaznon was the most effective insecticide with zero severity at 6DAS (Fig. 2 and Table 4) and hence, this insecticide is promising to be used as a control measure for cotton mealybug provided that other packages (application rate, time and others) are fulfilled.

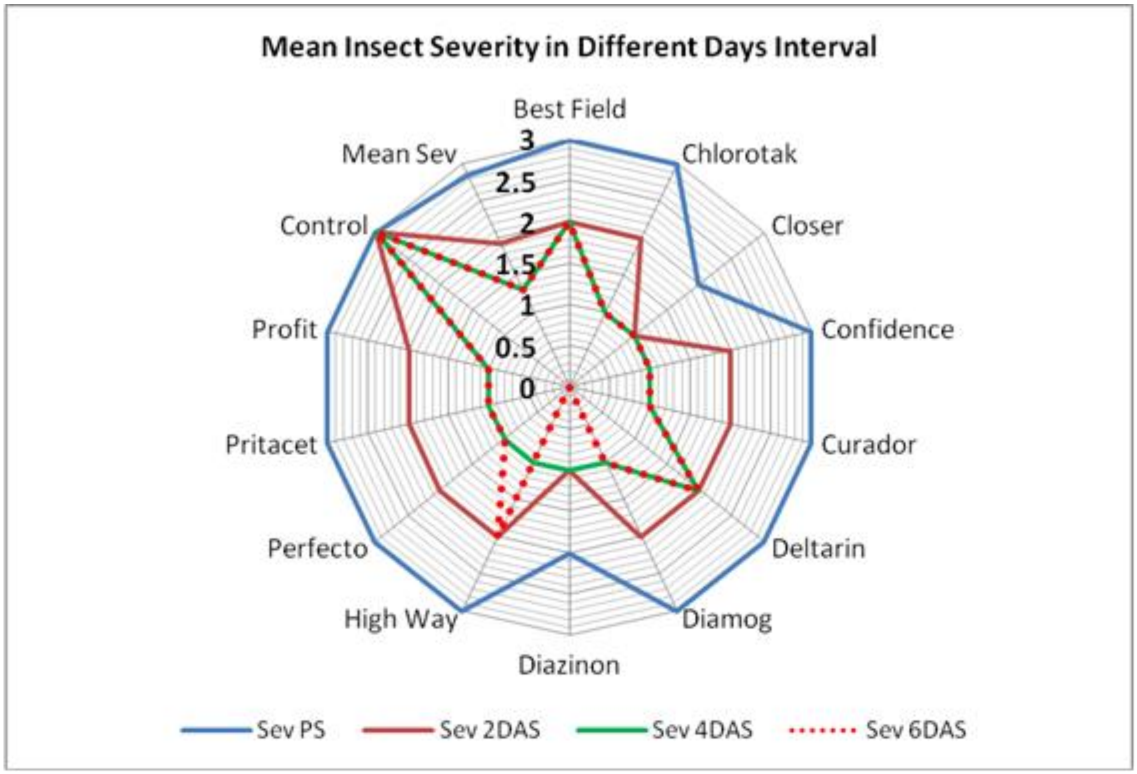

Figure 2: Mean incidence of cotton mealybug in different days interval after insecticide spray
Mean Sev: Mean severity; and others as described above

Conclusion

The pre-spray incidence level of farm-1 ranged from 73.33-100% while the pre-spray incidence level of farm-2 was 100% in all experimental plots. The highest incidence (100%) of the insect pest was recorded in the plots where Chlorotak, High Way and Profit insecticides were applied and, in the control, and the lower incidence (32.5%) at 2DAS was recorded from Diaznon. The highest efficacy of the insecticides was observed from Diaznon (86%) followed by Diamig (79%). Regardless of the insecticides type the mean incidence of the cotton mealybug decrsead as the time interval from when the insecticides applied increased and the highest cotton mealybug mean incidence (94.49%) before insectide sprayed (PS) finally deceased to (31.28%) at 6DAS of the insecticides. At 4DAS and 6DAS the severity of most of the insecticides was decreased to one (1) except for the control, Best Field, and Deltarin with the severity of 3, 2, and 2 respectively. The lowest incidence and zero severity of mealybug was observed from the insecticide Diaznon at 6DAS.

Recommendation

This study investigated that Diaznon is relatively better than the other insecticides and hence, farmers are advised to use this insecticide if the insect occurred. To increase the efficacy of this insecticide all other required practices like time of application, dose of application and others should be studied. Furthermore, a comprehensive research focusing on screening of different other insecticides and their application packages should be conducted. Awareness creation to farmers, experts, DAs and other stakeholders in the Western and adjacent woredas is critically important. In addition, pest assessment during the off season and removing the voluntary host plants, plowing the fields are also important to minimize the infestation of this insect pest.

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1.10. Participatory Varietal Evaluation of Bread Wheat (Triticum aestivum L.) Varieties in South Tigray

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Abstract

The highland areas of southern Tigray are one of the potentials for wheat production in the Tigray regional state. However, despite of its potential lack of access for improved wheat varieties is one of the limiting factors for low productivity of the crop in the area. Thus, this study aims to evaluate and select higher yielder bread wheat variety with full participation of farmers at their field. Four improved varieties were planted in a total of nine locations (6 farmers and 3 FTCs) during 2018/2019 production season. Data were collected from the experimental plots of all tested varieties and analyzed using descriptive analysis method with the help of SPSS software and ranking index. The result revealed that the variety ETBW7038 was scored a grain yield of 53 qt/ha, which shown a yield advantage increment by 32.5% as compared to the recently introduced kingbird variety. In addition, farmers were selected the variety ETBW7038 as first in all locations. Moreover, participant farmers were highly appreciated the variety ETBW7038 for its high grain yield, free to various diseases (like stem and leaf rust), and tolerant to logging as compared to the candidate varieties. Hence, the study conclude that the variety ETBW7038 is helpful to increase production and productivity of wheat in the highland districts of south Tigray and other similar agroecology by8.

Keywords: Bread Wheat, Ranking Index, Varieties

Introduction

Ethiopia is the largest producer of wheat in Sub-Saharan Africa. Bread wheat (*Triticum aestivum L.*) is among the most important food crops, which is extensively grown throughout the dry areas in the West Asia and North Africa regions (Su et al. 2011). The crop is mainly grown in the highlands of Ethiopia, includes Arsi, Bale, Shewa, Illubabor, Western Harerghe, Sidamo, Tigray, Northern Gonder and Gojam (Bekele et. al 2000). Recently, wheat in general has become one of the most important cereal crops (strategic crop) in terms of production and food security in Ethiopia (Tolesa 2014). Many wheat varieties have been released by national and regional research institutes that are adaptable to a wide range of environments. However, despite of the releasing a number of improved bread wheat varieties in the country, still many farmers continue cultivating local varieties, which are low yielders and highly susceptible to diseases (Haile *et al*. 2013).

The national productivity of wheat in the country is still very low, with a national average of 2.74 t/ha under smallholder farmers. More particularly, in Tigray region, the productivity of the crop is lower than the national average, which is about 1.98 t/ha (CSA 2018). Similar to the regional context, farmers grow both the improved and local varieties as well as using one variety year after a year in the study area is more common. Currently, most of the wheat varieties (bread wheat) used are highly exposed to various diseases and rust problems within short period of time. Participatory variety selection is an effective tool in facilitating the adoption of the improved technologies. Because, the users are allowed to participate in selecting appropriate technologies by employing their own selection criteria' and their own indigenous knowledge (Obsa et al., 2018; Witcombe et al. 2005; Getachew et al. 2002;). Farmers can adopt a technology according to various reasons considering their life experience and feasible advantages, like better productivity, yield stability, increased market value and based on measured traits (grain yield and rusts resistance) (Seifu et al. 2018).

Alamata agricultural research center was done different on station trials related to bread wheat varieties; as a result two varieties were showing significant yield difference as compared to the standard checks (Unpublished data). However, farmer perception towards the two promising genotypes is not known in the study area. Hence, this study was initiated to conduct participatory varietal evaluation of four improved bread wheat varieties through full participation of wheat growers. The objective of study was to select the best improved bread wheat variety/ies by involving farmers and asses the feedback of farmers towards the improved varieties.

Materials and Methods

Description of the study area

The study was conducted in Southern Zone of Tigray Regional State, Northern Ethiopia in 2018/19. Geographically, it is located between 12° 15‟ and 13° 41‟ N latitude and 38° 59‟and 39° 54‟ E longitude and with altitudinal range of 1350 to 3925 m above sea level. It shares common border with South Eastern Tigray zone in the North, Amhara regional state from the South and West, Afar Regional state from the east. The zone is characterized by three distinct agro-ecologies, including lowlands (locally named as *Kolla*), midland (*Weinadega*) and highland (*Dega*). The zone consists of five administrative Woredas, namely Raya Alamata and Raya Azebo from lowland agro ecology and Emba Alaje, EndaMehoniand Oflaworedas are found in the highland agro ecology of the zone (EIAR and TARI 2011) figure 1. The zone covers a total area of 4,985.72 km2, 498,572 and 143,326 ha cultivable land.

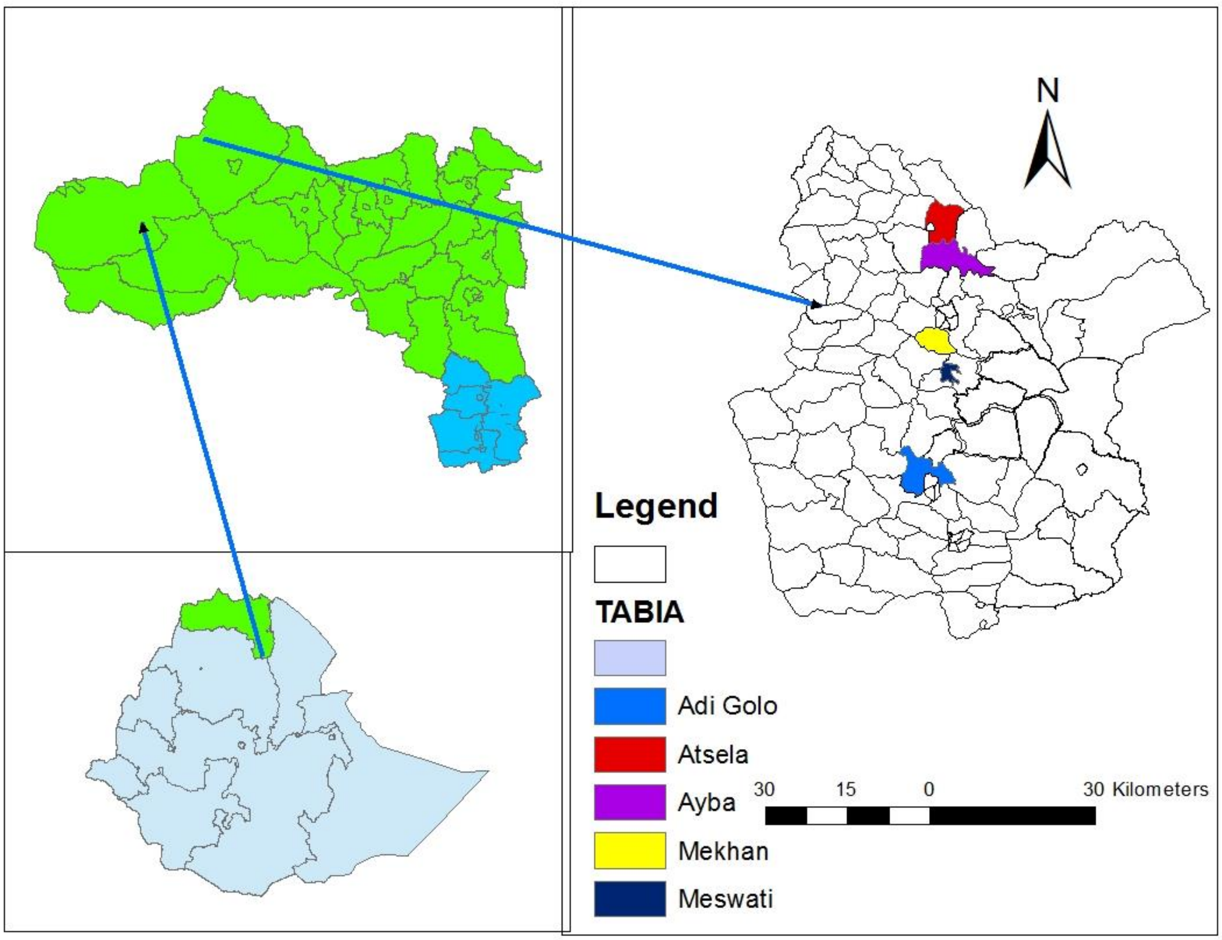

Figure 1. Map of the study areas (Arc Map, 2013).

The average land holding size of households in the zone ranges from 0.25 to 1.25 ha. However, the average landholding of the selected woredas ranges from 0.25 to 0.75 ha of land per household. Southern zone has experienced two rainfall seasons; the short rainy season locally known as "*Belgi*" that occurs usually from February to April and the main rain season locally described as “*kiremti*” that comes during June to September. On average, the area receives annually about 600 mm rainfall with mean annual temperature of 25°C. Wheat, barley, faba bean, and field pea are major crops grown on the highland agro-ecology (SZDCO, 2015).

Selection of kebelles and farmers

The selection of the districts and the kebelles was based on their potential for growing wheat. Both the kebelles and interested participant farmers were selected in collaboration with development agents of the respective kebelles. During 2018/19 production season the activity was implemented in a total of 9 locations (6 interested farmers and three farmers training centers) (FTCs) in Emaba Alaje district (Atselakebelle and Ayba), in Endamehoni district (Meswaeti and Mekan kebelles) and in Ofla district (Adigolokebelle). All participant farmers had planted four improved bread wheat varieties in a plot size of 10*10 m for each. The varieties were two candidates (ETBW8506 and ETBW7038) two standard checks (Hidase and kingbird) varieties.

Methods of data collection and analysis

The data on grain yield of the improved bread wheat varieties was collected using total harvest of 100 m^2 area of land, and threshed manually. Grain yield was weighed using sensitive balance and converted to hectare bases. In addition, the perception of farmers towards the varieties was evaluated through preparing list of variety attributes from farmers’ point of view. Farmers were asked to set bread wheat varieties selection attributes from their experience. Then after preparing the farmers preference traits based on their predetermined variety selection traits, and farmers were asked to rank the four varieties in each location. Finally, the collected data were analyzed using SPSS software and ranking index method.

Results and Discussion

Grain yield performance of the four varieties

As indicated in Table 1, the average grain yield of the ETBW7038 variety was 53 qt/ha, which have 32.5% yield advantage as compared the variety kingbird which is recently promoted by the office of agriculture and rural development district Offices. The grain yield recorded for the variety kingbird in the area is almost similar to grain yield recorded in the East Shoa of Oromia Region at Dugda and Lume Districts (Tesfaye and Fiseha 2018).

Table 1: Grain yield comparison of the varieties

Varieties	Mean (qt/ha)	Yield advantage/Standard
Hidase	37	-7.5%
ETBW8506	49	22%
Kingbird	40	-
ETBW7038	53	32.5%

NB. The yield advantage is calculated as compared to the standard check Kingbird variety

Farmers' selection criteria for bread wheat varieties at southern Tigray

Farmers were asked to list the selection criteria's of bread wheat varieties in all locations. Finally, they were agreed that they mainly used ten parameters to select one variety from another variety of wheat. Based on the farmers' selection criteria for bread wheat in Table 2**,** disease free, logging tolerant, seed weight and seed color attractiveness were the top four main criteria considered by farmers to select best variety of wheat according to their observation (Table 2).

Table 2: Farmers Selection criteria for wheat

Selection criteria	**Weighted value**	**Index value**	**Ranking**
Disease free	33	0.153	1
Logging tolerant	30	0.139	2
Seed weight	26	0.120	3
Seed color attractiveness (market)	22	0.102	4
Tillering capacity	20	0.093	5
Heading length	20	0.093	5
Yield	19	0.088	6
Earliness to mature	11	0.051	7
Treshability	10	0.046	8
Palatability for animal feed	10	0.046	8
Sum	216	1.000	

Based on the ten predetermined criteria in Table 2, the variety ETBW7038 was ranked first which was requested for national releasing committee to register as variety nationally and kingbird variety was also selected second based farmers preference (Table 3). On the other hand, farmers highly dislike the variety Hidase at Meswaeti and Atsela Kebelles as compared to the other varieties. The results of the study have very important implication for researchers and other stakeholder which involved in technology generation, evaluation and dissemination. For instance, the variety ETBW8506 had higher score than kingbird, but farmers were selected kingbird than the ETBW8506 which have 9 qt/ha yield difference (Table 1; Table 3).

Previously, producer farmers were reported that Kingbird variety was highly preferred for its water logging tolerant and earliness by the farmers at Raya Alaamata district (Hagos *et al.*, 2019). In similar way, the variety ETBW7038 was showed better performance in tolerance to various diseases (like stem and leaf rust), high grain yield and logging tolerant as compared the variety kingbird. The better performance of the variety to the set criteria may reflect the importance of the variety to the study area. Similar to this finding, disease and insect tolerance was the key trait and ranked first in bread wheat participatory variety selection (Mancini *et al.*, 2017; Seifu et al., 2018).

Table 3. Final evaluation of the improved bread wheat varieties

				Ranking index						
varieties	Adigolo	Meswaeti	Atsela	1	2	3	4	Wt	Index	Rank
Hidase	2	4	4	0	1	0	2	5	0.17	4
ETBW8506	3	3	3	0	0	3	0	6	0.20	3
Kingbird	4	2	2	0	2	0	1	7	0.23	2
ETBW7038	1	1	1	3	0	0	0	12	0.40	1
				12	**9**	**6**	**3**	**30**	**1.00**	

Conclusion and Recommendation

Farmers used different parameters and methods to evaluate the tested wheat in all locations of South Tigray. For fast adoption and dissemination of a new variety, considering the preferences of farmers and consumers are necessary, otherwise it is less likely to be widely adopted or accepted by growers of an area. The results of the trials have demonstrated that, out of the four improved bread wheat varieties, two varieties, namely, ETBW7038 and Kingbird were preferred by farmers based on the evaluation merits in the area. This implies that evaluating the existing improved crop varieties through farmers' participation is a prerequisite for wider adoption and scaling up of the crop. In conclusion, the candidate ETBW7038 was recorded higher grain yield and selected first by farmers in all locations. Therefore, it is highly advisable to demonstrate the nationally requested variety in all the study locations in the coming season.

Acknowledgement

The authors are thankful to agricultural experts of Ofla, Emba-Alaje and Endamehoni district experts and development agents for their support during farmers and site selection. We would like to acknowledge AGP II project for their financial support. We would also like to thank Alamata Agricultural Research Center of TARI (Tigray Agricultural Research Institute) staff members for their support to conduct the study.

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1.11. Participatory Varietal Evaluation of Faba Bean (*Vicia Faba* l.) Varieties in South Tigray

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Abstract

The highland areas of southern Tigray are one of the potential for faba bean production in the region. However, despite of its potential lack of access for improved faba bean varieties is one of the limiting factors for the area. Thus, this study aims to evaluate and select higher yielder faba bean variety in the areas. Three improved and one local check faba bean varieties were planted at nine sites (6 sites at Emba Alaje and 3 sites at Ofla districts) during 2018/19 production season. Yield data of the four varieties were collected from all sites while the perception data were collected from two sites per location. Data were analyzed using descriptive analysis method with the help of R-software and ranking index. The result of the analysis shown that, there was no significance difference in grain yield among the tested varieties. However, farmers selected Numan for its shorter in 1st pod bearing length, earliness, grain yield, seed size and seed uniformity. Therefore, further study is required to demonstrate or popularized the selected variety in the study area and other similar agro-ecologies.

Keywords: Faba bean, Varieties, Ranking index.

Introduction

Faba bean (*Vicia faba L.*) is originated in the Far East and is one of the earliest domesticated legumes crops after chickpea and pea (Tafere et al. 2012). It is one of the best crops among the grain legumes (Singh *et al*. 2013). The crop is also one of the major pulse crops grown in the highlands (1800–3000 m.a.s.l) of Ethiopia (Temesgen and Aemiro, 2012; Tafere et al. 2012). Ethiopia is the second largest producers of faba bean in the world, next to China (Biruk, 2009). However, national productivity of faba bean in the country is still very low, with a national average of 2.09 t/ha under smallholder farmers. More particularly, in Tigray region, the productivity of the crop is lower than the national average, which is about 1.64 t/ha (CSA 2018).

Pulses in general contribute to smallholder livelihoods in multiple ways. Firstly, pulses can play a significant role in improving smallholders' food security, as an affordable source of protein (pulses make up approximately 15% of the average Ethiopian diet). Secondly, pulse can have an income benefit for smallholders, both in terms of diversification and because they yield a higher gross margin than cereals (IFPRI 2010). In similar ways, faba bean serves as source of food with a valuable and cheap source of protein, starch, cellulose and minerals (Haciseferogullari et al. 2003). Faba bean is a high value crop that fetches high income to farmers. It is an important rotation crop which farmers are using to restore the fertility of their plots (Negash et al. 2015).

In southern Tigray, faba bean crop is widely used for human food in different forms like *sprouted bean* and *green pod* alone and stews *("whot")* with other mixtures. In addition, farmers commonly used faba bean as crop rotation with cereal crops like wheat and barley for soil fertility improvement as well as disease and insect pest break (Kidane and Brhane 2018). Hence, the price of faba bean is higher than the other cereal crops. On the other hand, the productivity of faba bean is still remains low due to different problems. Less access of improved varieties is one of the main problems in the study area. Thus, this study was aimed to evaluate and select high yielder variety that confirmed by the farming community.

Materials and Methods

Area description of the study area

The present research was carried out in Ofla and Emba Alaje districts of southern Tigray, Ethiopia. Ofla district is located at 12^{o}31'N latitude and 39^{o}33'E longitude. The altitude varies between 1700 - 2800 meter above sea level. The annual rainfall varies from 450 mm to 800 mm during keremt and 18 mm to 250 mm during Belg season. Wheat, barley, faba bean, field pea and lentil are the dominant crops grown in Ofla district. Wheat and barley are the major sources of daily foodstuffs (RAARDO 2018). About 42% of the area is *categorized to* high land agro-ecology (locally called *"dega")*, 29% to mid land ("*weina-dega")* and 29% of it is in the low land ("kola") agro-ecology.

On the other hand, Emba Alaje district is also located between 14.22^{0} and 14.39^{0} north latitude and 53.05^{0} and 56.01^{0} east longitude, and lies at an average altitude of 2350 meters above sea level. The mean annual rainfall of the district is 912 mm with a mean daily temperature ranges between 9 - 23^{0}c. The important major crop commodities grown in the district include wheat, barley and faba bean (Tesfay et al. 2014).

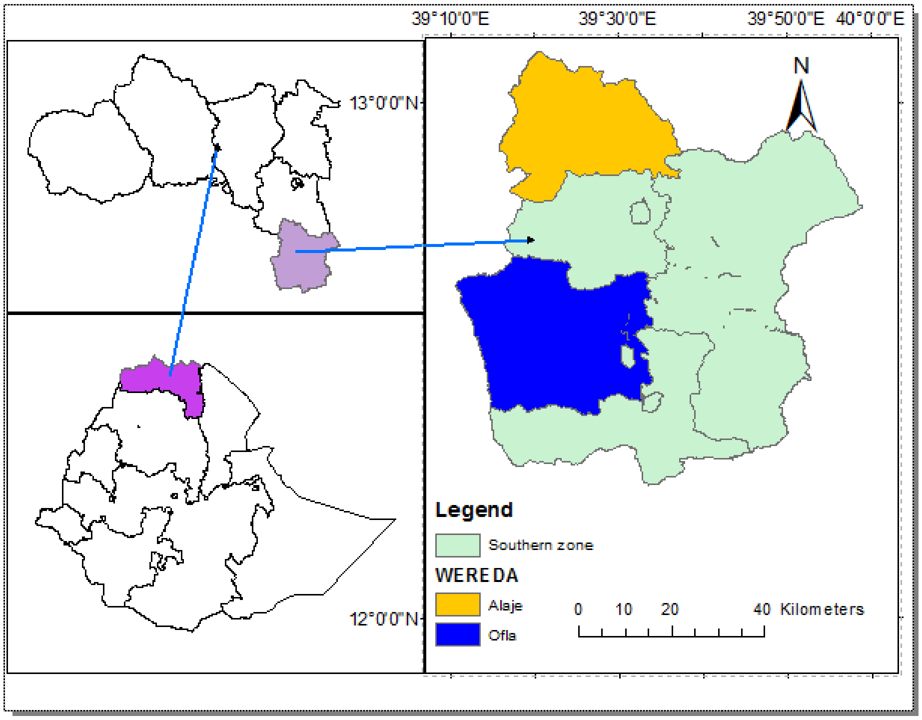

Fig 1. Map of the study areas: (Arc Map 2013).

Selection of kebelles, farmers and approaches used

The selection of the districts and the kebelles was based on their potential for faba bean production. Both the kebelles and interested participant farmers were selected in collaboration with development agents of the respective kebelles. The activity was implemented in a total of 6 interested farmers and three farmers training centers (FTCs) in Emaba Alaje district (Ayba and Atsela kebelles), and in Ofla district (Hashenge kebelle) in 2018/19 production season. All participant farmers had planted four varieties and the size of the experimental plots was 10 m by 10 m with 40 cm and 10 cm row and plant spacing in that order. The three varieties were consisted of one candidate variety (EHO7005-1), two standard checks (Walki and Numan) and 1 local check in single replication over locations were planted.

Data collection and analysis

The data on grain yield of both local and improved faba bean varieties was collected using total harvest of 100 m^2 area of land and threshed manually. Grain yield was weighed using sensitive balance and converted to hectare bases. In addition, the perception of farmers towards the varieties was evaluated by preparing list of variety attributes from farmers' perceptin. Farmers were asked to set faba bean varieties selection attributes from experience. Then after preparing the farmers preference traits based on their predetermined variety selection traits, and farmers were asked to rank the four varieties. During the pod maturity of the tested varieties farmers were make their evaluation. Moreover, data was analyzed using R-software and ranking index.

Results and Discussions

Grain yield performance of the four faba bean varieties

The result of the study indicated that there is no significant difference on average grain yield of the varieties at less than 1% significance level (Table 1). Farmers' selection criteria and their perception (table 2).

Table 1. Mean yield performance of the varieties at Emba-Alaje (Ayba and Atsela), and Ofla (Hashenge) locations in 2018,Ethiopia

	Grain yield (qt/ha)			
Variety	Atsela	Ayba	Hashenge	Mean
Numan	26.29a	34.07a	15.71a	25.36a
ETO7005-1	27.75a	43.84a	22.63a	31.41a
Walki	20.73a	39.63a	14.06a	24.80a
Local	21.88a	27.41a	17.46a	22.25a
P value	0.89	0.49	0.65	0.75

Table 2. Farmers' selection criteria for faba bean varieties

Selection criteria	Weighted Value	Index value	Ranking
Disease and pest tolerant	21	0.184	1
Earliness	18	0.158	2
Higher yielder	16	0.140	3
Number of pods per plant and pod bearing length	14	0.123	4
Seed size	13	0.114	5
Number of seeds per pod	13	0.114	5
Branching capacity	8	0.070	6
Plant height	6	0.053	7
Seed uniformity	5	0.044	8
	114	1.000	

Based on the farmers' selection criteria for faba bean varieties in Table 2**,** disease and pest tolerant, earliness and higher yielder were the main criteria considered by farmers to select best variety according to their observation. Finally, based on the nine predetermined criteria, the variety Numan was selected first and the local variety came second. Whereas, the ETO7005-1 which was requested for national releasing committee was ranked last based on farmers' perception (Table 3). This result implies very important lesson for the biological researches especially for those involves in breeding and varietal evaluation. Accordingly, Numan ranked 1st in two location for its shorter in 1st pod bearing length, earliness, grain yield, seed size and seed uniformity. Therefore, participant farmers preferred and selected Numan variety as first and the candidate (ETO7005-1) the last based on their selection criteria (Table 3), and they decided for further participation in demonstration and popularization of the Numan variety.

Table 3. Final evaluation of the varieties

				Ranking index						
Variety	Atse	Hash	Ayb	1st	2nd	3rd	4th	Wt	index	Rank
Numan	1	3	1	2	0	1	0	10	0.33	1
Et070051	4	4	4	0	0	0	3	3	0.10	4
Walki	3	1	3	1	0	2	0	8	0.26	3
Local	2	2	2	0	3	0	0	9	0.30	2
Total				12	9	6	3	30	1.00	

Conclusion and Recommendation

Farmers used different parameters and methods to evaluate the tested faba bean varieties in all locations of South Tigray. For fast adoption and dissemination of a new variety, considering the preferences of farmers and consumers are necessary, otherwise it is less likely to be widely adopted or accepted by faba bean growers of an area. In this trial, in conclusion, there is no significance difference between the varieties in grain yield across all locations. In this case, farmers' preference was the prior criteria to select the varieties. Accordingly, farmers were selected the variety Numan first than the other varieties. Therefore, it is highly advisable to demonstration the variety Numan in all the study locations in the coming season.

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2. Natural Resources Management Technologies

2.1. Effects of Different Levels and Time of Application of Slow Releasing N Fertilizer (UREA^{Stabil}) on growth and yield of Teff on Vertisol

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Abstract

This study was initiated to compare (UREA^{Stabil}) with conventional urea in time and rate of application, on yields and yield components of teff. Design was RCBD with 12 treatments. Soil sample was taken and analyzed followed the laboratory procedures. All gronomic data was collected timly. The soil textural class is clay and loam. Physiological maturity, panicle length and plant length was significantly ($P \leq 0.05$) affected by slow releasing nitrogen fertilizer rates on of Teff yield. Biological yield of teff was significantly ($P \leq 0.05$) influenced by the effect of different slow nitrogen releasing fertilizer. Biomass production 32 kg UREA^{Stabil}ha^{-1}(1/3 at planting and 2/3 at tillering) + basal. Grain yield of teff was significantly ($P \leq 0.05$) influenced by the different rates of slow nitrogen releasing fertilizers and increased with an increase in UREA^{Stabil} rates (0 to 96 kg N ha^{-1}). The highest grain yield (1906.6 kg ha^{-1}) was obtained in response to application of 32 kg UREA^{Stabil} ha^{-1} with 39% increase over that of control. Straw yield was significantly affected by slow nitrogen releasing fertilizer rates ($P \leq 0.05$). Increasing slow nitrogen releasing fertilizer rates UREA^{Stabil} enhanced teff straw yield. The effect of different rates of nitrogen on teff harvest index was significant ($P\leq 0.05$). Nitrogen fertilizer at a rate of 96 kg N ha^{-1}from slow nitrogen releasing fertilizer (UREA^{Stabil}) for teff production is found economically best, thus; should be used as a bench mark for further study on slow nitrogen releasing fertilizers for teff.

Keywords: Nitrogen fertilizer, Slow releasing, teff, Urea^{stabil} , yield

Introduction

Nitrogen (N) is often the most limiting nutrient for crop yield in many regions of the world. Nitrogen fertilizer is one of the main inputs for cereals production systems. The increase of agricultural food production worldwide over the past four decades has been associated with a 7-fold increase in the use of N fertilizers (Hirel et al 2007). Therefore, application of nitrogen fertilizer at the right rate and time is vital for the enhancement soil fertility and crop productivity.

Availability of nitrogen applied as fertilizer to crop depends not only on the rate but also on the nature of the N fertilizer, soil types and conditions, cropping system, management as well as on temperature and precipitation during the growing season (Przulj and Momcilovic 2001). Highly soluble N fertilizers like urea may be lost from the soil plant system through leaching, NH_3 volatilization, denitrification and immobilization or may be fixed on the soil colloids as NH_4-N form (Bock 1984). Urea has a major disadvantage; considerable amounts of N can be lost through volatilization which might be resulted in very low N fertilizer use efficiency (Chen et al 2008), if not incorporated into soil soon after application. The N recovery by crops from the soluble N fertilizers such as urea is often as low as 30–40%, with a potentially high environmental cost associated with N losses via NH_3 volatilization, NO_3^- leaching and N_2O emission to the atmosphere (Zhou et al 2003). Because of these reasons nitrogen fertilizer use efficiency in the case of urea is very low.

There are different mechanisms to improve the nitrogen fertilizer use efficiency. Cropping system, soil and water management, use of appropriate N fertilizer and application rate are among the main management options to increase N fertilizer use efficiency. In addition to these, use of slow N releasing fertilizers, nitrification inhibitor, efficient species or genotypes, and disease, insects and weeds control are also important for improvement of N fertilizer us efficiency (Fageria 2009). However, some of the management options listed above are not being practiced in Ethiopia in general and Tigray region in particular. For instant, slow N releasing fertilizers and nitrification inhibitors are not being practiced at T/koraro district.

According to Jiao et al (2004), to boost up the urea-N recovery and reduce its loss, many forms of slow N releasing urea fertilizers have been developed and applied to different plant species under a range of environmental conditions. The products may be coated, chemically and biochemically modified, or are granular. Such slow N releasing urea fertilizers can increase the efficiency of applied urea-N. These fertilizers are environmentally friendly because of their N releases in synchronous with plant N uptake. A single application of these fertilizers can supply sufficient amount of N at equivalent rate for plant N requirements while maintaining very low concentrations of mineral N in soil system throughout the growing season (Bacon 1995).

Slow N releasing fertilizers involve a slower release rate than conventional water-soluble fertilizers, but the rate of release is not controllable and depends on types and population of microbial organisms in the soil. The existence and effectiveness of the microorganisms in solubilizing the fertilizer again depend on soil properties and conditions such as soil temperature and moisture (Trenkel 2010). Thus, the rate of N release from slow releasing fertilizer is a function of soil properties and conditions.

Slow nitrogen release urea fertilizers can increase nitrogen use efficiency through either slowing the release rate or by altering reactions that lead to losses (Kathrine 2011). UREA^{stabil} is one form of slow nitrogen releasing urea. The nitrogenous fertilizer UREA^{Stabil} is urea enriched with the inhibitor of urease NBPT (N-(nbutyl)-thiophosphorictriamide). It is a new fertilizer that was registered in the Czech Republic in 2006.UREA^{Stabil} reduces losses due to volatilization, leaching and denitrification (Mraz 2007). Nitrification inhibitors (NI) could slow nitrification and increase N assimilation, yield and also increase the nitrogen use efficiency (Freney et al 1992). The rate and split N applications affect both yield and grain quality (Subedy et al 2007) which are the main factors affecting crop profitability.

In Tahtay koraro district application of N as urea fertilizer and P as DAP at the rate of 100 kg urea and 100 kg DAP is a recommended rate to boost up teff production and productivity. However, teff production and productivity have been declining from year to year. In both districts, leaching and denitrification may be the causes for N loss from urea fertilizer due to the vertisols soil nature and high rain fall. Therefore, appropriate source of N fertilizer, rate and time of application may improve N fertilizer use efficiency of the crop. Furthermore, rate and time of application of slow nitrogen releasing fertilizer (UREA^{Stabil}) on yields and nyield components of teff is not well investigated at T/koraro district. Therefore, a study was initiated; i) to compare the effects of slow nitrogen releasing fertilizer (UREA^{Stabil}) with conventional urea fertilizer on yield and yield components of teff and ii) to evaluate appropriate time and rate of application of slow nitrogen releasing fertilizer ($UREA^{Stabil}$) for teff at both locations.

Materials and Methods

Description of the study area

A field experiment was conducted during the 2016 and 2017 cropping season on selected farmers' field at T/koraro district, northwestern Tigray, northern Ethiopia (1957 m.a.s.l 14°3'17.535"N , 38°18'45.099"E). Soil type of the study area is mainly vertisol. The district is categorized under the semi-arid tropical mid highlands (SA_3) belt of Ethiopia where most of the middle altitude crops such as *teff (Eragrostic teff*), fababean (*Vicia faba* L.), and chickpea (*Cicerarietinum* L.) are commonly grown. The area is characterized by uni-modal rainfall pattern. The average maximum and minimum temperatures were 28.87 and 13.86 ^{0}C, respectively.

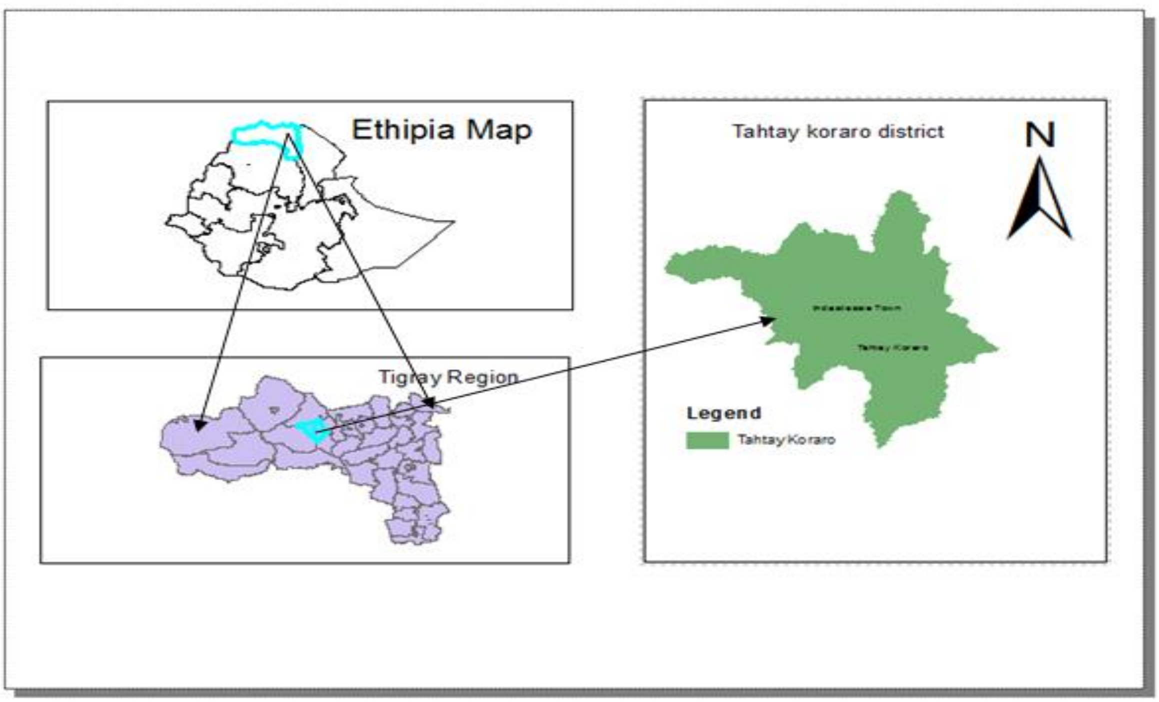

Figure 1: Map of the study area

Experimental design and treatment

The experiment was arranged in a randomized complete block design (RCBD) replicated three times. The full experiment was conducted at two farmer's field T/koraro for teff. Plot size was decided to be 3 m by 3 m (9 m^2). The spacing between blocks, plots and plant rows was 1 m, 0.5 m and 20 cm, respectively. The trial area was sown to teff (cv. Quench) on 2016 and 2017 cropping seasons, at a seed rate of 10 kg ha^{-1}.

Phosphorus in the form of triple super phosphate (TSP), potassium in the form of murate of potash (KCl) and sulfur in the form of $CaSO_4$ were applied at the rate of 46 kg P ha^{-1} (P_2O_5), 60 kg K ha^{-1} (K_2O) and 30 kg S ha^{-1}, respectively. All the fertilizers were applied as basal application to all plots.

Treatments;

1. 0 (with no N fertilizer + basal)
2. 32 $UREA^{Stabil}$ at planting + basal
3. 48 $UREA^{Stabil}$ at planting + basal
4. 64 $UREA^{Stabil}$ at planting + basal
5. 96 $UREA^{Stabil}$ at planting + basal
6. 64 conventional urea at planting (recommended rate) + basal
7. 32 $UREA^{Stabil}$ (1/3 at planting and 2/3 at tillering) + basal
8. 48 $UREA^{Stabil}$ (1/3 at planting and 2/3 at tillering) + basal
9. 64 $UREA^{Stabil}$ (1/3 at planting and 2/3 at tillering) + basal
10. 96 $UREA^{Stabil}$ (1/3 at planting and 2/3 at tillering) + basal
11. 64 conventional urea (1/3 at planting and 2/3 at tillering) recommended rate) + basal
12. 96 conventional urea (1/3 at planting and 2/3 at tillering) recommended rate) + basal

Soil sampling and sample preparation

Before planting two composite soil samples (one composite sample per site) were collected from 0-20 cm depth. After harvesting soil sample from plots that receive same treatment (twelve samples per farmers' fields) were collected. The soil samples were transported to Shire soil laboratory for the analysis of selected soil parameters. The samples were subjected to dry at an ambient temperature, ground and sieved through a 2 mm sieve and be ready for analyses.

Soil 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 and pH glass electrode (Rhoades 1982). Organic matter will be determined by wet oxidation method as described by (Walkely and Black 1934). Available P will be determined by (Olsen and Watanabe 1954) method. Total nitrogen was determined using Kjedahl method as described by (Bremner and Mulvaney 1982). Cation exchange capacity and exchangeable bases were determined as described by (FAO 2008).

Agronomic data collected

Plant height (cm): measured from the soil surface to the tip of the spike excluding the awns at physiological maturity.

Head length (cm):measured in cm from the base of the spike to the top of the last spikelet excluding awns.

Effective tillers per plant: The average number of productive tillers per plant

Days to heading: The number of days from date of sowing to the stage where 50% of the heads have fully emerged.

Days to physiological maturity: The number of days from the date of sowing to the stage where 90% of the plants in the plot reached physiological maturity.

Grain yieldha^{-1}(kg ha^{-1}): Grain yield obtained from each plot was used to estimate grain yield in kg per hectare.

Biomass yields (kg ha^{-1}): The plants with in the plot by excluding the border rows were harvested at the point where they are attached to the ground, collected and air dried until it attained constant weight and weighed to obtain the biological yield.

Harvest index (HI%): Calculated on a plot basis, as the ratio of dried grain weight to the dried total above ground biomass weight and multiplied by100.

Data for the plant height, number of effective tillers and head length were measured by randomly selecting 10 plants from each experimental plot. The averages of the ten plants in each experimental plot were used for statistical analysis.

Data analysis

The data was subjected to statistical analysis. Analysis of variance (ANOVA) was carried out using SAS software program using SAS version 9 (SAS, 2002). 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).Variable cost of conventional urea and slow releasing (UREA^{stabil}) fertilizers was largely subjected to partial budget analysis**.** Price fluctuations during the production season were considered. Marginal Rate of Return, which refers to net income was obtained by incurring a unit cost of fertilizer, was calculated by dividing the net increase in yield of wheat due to the application of each rate to the total cost of conventional urea and slow releasing (UREA^{stabil}) fertilizers applied at each rate. This enables to identify the optimum rate and source of urea fertilizer for bread wheat production (CIMMYT 1988).

Results and Discussion

Physico-chemical properties of the soil

The physical and chemical properties of the experimental site analysed in laboratory and presented in table (Table). The textural class of the all experimental sites during both cropping seasons except site 2 in the first year were similar. The textural class of the soil for these three sites is clay whereas the second site during year one was loam. According to the Hazelton and Murphy (2007) rating , the soil reaction is moderately acidic in all experimental sites. As per the organic carbon rating suggested by Tekalign (1991), organic carbon content of the soil is low in all experimental sites. According to Olsen (1954), the available P was also rated as low in all experimental sites.

Table1. Physical and chemical soil results of experimental sites during both years

	Experimental sites year1		Experimental sites year2	
Parameters	Site 1	Site 2	Site 1	Site 2
pH	6.56	6.98	6.71	7.45
EC(mmh)	0.223	0.4069	0.216	0.3988
Ava. P	6.32	8.973	2.892	10.951
% OC	0.745	0.616	0.560	0.636
%)OM	1.281	1.061	0.965	1.096
CEC	34	36.8	42	48
% Sand	14	37	14	16
% Silt	32	37	32	35
% Clay	54	23	54	49
Tex. Class	clay	Loam	Clay	Clay

Effects of Urea^{stabil} fertilizer rates on phonological and growth traits of teff

Days to 50% heading

Days to 50% heading was significantly ($P \leq 0.05$) affected by slow releasing nitrogen fertilizer rates. Plants grown at the rate of 32 kg UREA^{Stabil} ha^{-1} (1/3 at planting and 2/3 at tillering) + basal and 96 kg UREA^{Stabil} ha^{-1} at planting plus basal had significantly hastened days to panicle emergence though in statistical parity with most of the other rates (Table 2). Generally, the number of days to 50% heading recorded over all the treated plots was significantly lower than the unfertilized plot (Table 2). The maximum number of days took the teff plant to reach 50% heading was observed on the plots which were treated with no nitrogen (0 kg N ha^{-1}).

Days to physiological maturity of teff plant was significantly ($P \leq 0.05$) the slow releasing nitrogen fertilizer rates. The physiological maturity of teff plant was hastened mostly for higher UREA^{Stabil} rates and in some cases for lower rates. The early maturity of plants on the plots received higher UREA^{Stabil} rates might be due to the late drought that cause forced maturity, because under these higher N rates the moisture was not enough for the highly vegetated plant biomass thereby started to mature early. In contrast, to this study, Marschner (1995); Tanaka et al (1995) and Brady and Weil (2002) reported higher N applied than required, delayed plant maturity. On the other hand, the early maturity of teff on plots received lower UREA^{Stabil} rates might also be due to the shortage of nitrogen.

Table 2: Days to 50% heading and 90% maturity, plant height and panicle length of teff as influenced by UREA^{stabil} fertilizer rate in 2016 and 2017 main cropping season.

Treatment	DH (days)	DM (days)	PH (cm)	PL (cm)
0 (with no N fertilizer + basal)	65.33^{a}	110.75^{a}	96.12^{e}	42.58^{c}
32 UREA^{Stabil} at planting + basal	63.17^{ab}	110.17^{ab}	103.23^{ed}	44.42^{bc}
48 UREA^{Stabil} at planting + basal	62.33^{abc}	108.92^{b}	111.85^{bc}	47.18^{bc}
64 UREA^{Stabil} at planting + basal	60.67^{bc}	109.08^{ab}	114.42^{abc}	47.93^{abc}
96 UREA^{Stabil} at planting + basal	59.58^{c}	108.75^{b}	121.10^{a}	49.23^{ab}
64 CU + basal	60.50^{bc}	108.92^{b}	117.08^{ab}	48.60^{ab}
32 UREA^{Stabil} (1/3 by 2/3)* + basal	59.58^{c}	108.50^{b}	120.40^{a}	49.57^{ab}
48 UREA^{Stabil} (1/3 by 2/3)* + basal	61.58^{bc}	109.25^{ab}	108.18^{cd}	45.58^{abc}
64 UREA^{Stabil} (1/3 by 2/3)* + basal	62.75^{abc}	109.33^{ab}	110.08^{bcd}	48.57^{ab}
96 UREA^{Stabil} (1/3 by 2/3)* + basal	60.67^{bc}	109.33^{ab}	115.07^{abc}	48.03^{abc}
64 CU (1/3 by 2/3)* + basal	61.83^{bc}	109.25^{ab}	112.50^{cd}	48.07^{abc}
96 CU (1/3 by 2/3)* + basal	61.17^{bc}	108.83^{b}	117.07	50.40^{a}
Mean	61.60	109.26	112.26	47.51
LSD (P≤0.05)	3.36	1.73	7.5382	5.87
CV (%)	3.96	1.16	4.94	9.09

Where; DH= Days to 50% heading, DM= Days to 90 % Maturity, PH= Plant height, PL= Panicle length, LSD= least significant difference and CV= coefficient of variance.

Plant height and panicle length

The analysis of variance showed that plant height and panicle length were highly significant (P≤0.05) influenced by slow releasing nitrogen fertilizer rates. Plant height was increased with the increase in the application rates of UREA^{stabil} (Table 2). Though it is not consistent, plants on plots treated with higher rates of nitrogen were taller than plants on plots treated with lower rates of nitrogen. The tallest plants were obtained from the plots received nitrogen rate of 96 kg UREA^{stabil} ha^{-1}.In line with this study, Abraha (2013) also reported that, plant height increased with increasing N rates to the level of 69 kg N ha^{-1}.

Out of all plots received different rates of nitrogen, the shortest plants were observed from plots which received no nitrogen fertilizer. Many studies revealed significant influence of N on plant height as it plays vital role in vegetative growth of plants. This may be attributed to the fact that N usually favors vegetative growth of teff, resulting in higher stature of the plants with greater panicle length. Legesse (2004) also reported that application of higher N rates resulted in teff plants with significantly taller height due to direct effect of N on vegetative growth of crop plants. The plant height obtained from unfertilized plot was significantly shorter than all treated plots although statistically in par with 32 kg ha^{-1} UREA^{Stabil} applied at planting.

Having some inconsistencies increasing nitrogen rate from 0 kg N ha^{-1} to 96 kg UREA^{Stabil} ha^{-1} was also increased panicle length of teff. The highest panicle length was recorded on plots received 96 conventional urea (1/3 at planting and 2/3 at tillering) recommended rate), but statistically, the same with the panicle length recorded from most plots. This result is similar with that of Haftamu et al (2009) who reported that teff panicle length increased in response to increasing rate of nitrogen application, with the longest panicles being obtained at the highest rate 92 kg N ha^{-1} of nitrogen.

Effects of urea^{stabil} fertilizer on yield and yield components of teff

Biomass yield

The analysis of variance showed that biological yield of teff was significantly ($P \leq 0.05$) influenced by the effect of different slow nitrogen releasing fertilizer. teff biomass production was relatively greater for teff received 32 kg UREA^{Stabil} ha^{-1} (Table 3).

Table 3: Biomass yield, grain yield, straw yield and harvest index of teff as influenced by UREA^{stabil} fertilizer rate in 2016 and 2017 main cropping season.

Treatment	BY (kg/ha)	GY (kg/ha)	SY (kg/ha)	HI (%)
0 (with no N fertilizer + basal)	4765.00^{c}	1166.60^{d}	3598.40^{c}	24.35^{ab}
32 UREA^{Stabil} at planting + basal	5459.40^{bc}	1404.30^{bcd}	4055.10^{bc}	25.56^{ab}
48 UREA^{Stabil} at planting + basal	6143.20^{abc}	1618.00^{abc}	4525.20^{abc}	25.53^{ab}
64 UREA^{Stabil} at planting + basal	6730.80^{ab}	1630.40^{abc}	5100.30^{ab}	24.19^{ab}
96 UREA^{Stabil} at planting + basal	7532.10^{a}	1843.10^{a}	5688.90^{a}	24.32^{ab}
64 CU + basal	6752.10^{ab}	1651.60^{abc}	5100.50^{ab}	24.40^{ab}
32 UREA^{Stabil} (1/3 by 2/3)* + basal	6523.5^{bc}	1651.6^{a}	5700.30^{a}	26.31^{a}
48 UREA^{Stabil} (1/3 by 2/3)* + basal	5779.90^{cb}	1349.90^{cd}	4430.00^{abc}	23.24^{b}
64 UREA^{Stabil} (1/3 by 2/3)* + basal	6410.30^{abc}	1687.00^{abc}	4723.20^{abc}	25.95^{ab}
96 UREA^{Stabil} (1/3 by 2/3)* + basal	6944.40^{ab}	1724.10^{ab}	5220.30^{ab}	24.47^{ab}
64 CU (1/3 by 2/3)* + basal	6474.40^{abc}	1722.90^{ab}	4751.40^{abc}	26.25^{a}
96 CU (1/3 by 2/3)* + basal	6997.90^{ab}	1778.30^{a}	5219.60^{ab}	25.07^{ab}
Mean	6376	1608	4769	25
LSD (P≤0.05)	1566	442	1192	3.6
CV (%)	30	34	31	18

Where; BY= Biomass yield, GY= Grain yield, SY= Straw yield, HI= Harvest Index, LSD= least significant difference, CV= coefficient of variance and *= 1/3 at planting and 2/3 at tillering.

Biomass yield was also increased with an increase in the rates of slow nitrogen releasing fertilizer (UREA^{Stabil}). The highest biomass yield (7606.8 kg ha^{-1}) was obtained from plots treated with 32 UREA^{Stabil} (1/3 at planting and 2/3 at tillering) + basal (Table 3) whereas the lowest biomass yield was obtained from the untreated plots.

Grain yield

The analysis of variance showed that grain yield of teff was significantly ($P \leq 0.05$) influenced by the different rates of slow nitrogen releasing fertilizers. Grain yield of teff increased with an increase in UREA^{Stabil} rates (0 to 96 kg N ha^{-1}). The highest grain yield (1906.6 kg ha^{-1}) was obtained in response to application of 32 kg UREA^{Stabil} ha^{-1} with 39% increase yield over that of control (Table 3). Nevertheless, except the plots received 0, 32 (applied at planting) and 48 kg UREA^{Stabil} ha^{-1} (split applied) it was statistically equal with the grain yield obtained in response. The lowest grain yield (1166.60 kg ha^{-1}) was obtained from plots under continuous teff mono cropping. Benefit of slow nitrogen releasing fertilizers is the yield advantage associated with continuous supply of N availability to a crop.

Straw yield

Straw yield of teff was highly significantly affected by slow nitrogen releasing fertilizer rates ($P \leq 0.05$). Increasing slow nitrogen releasing fertilizer rates (UREA^{Stabil}) enhanced teff straw yield. The highest straw yield was obtained in response to applying 32 kg UREA^{Stabil} (Table 3) but statistically the same with all treatments excluding plots received 0 and 32 kg UREA^{Stabil}ha^{-1} (applied at planting time).

Harvest index

Harvest index (HI) is the ability of a crop to convert the total dry matter into economic yield. Harvest index was calculated as the ratio of grain yield to the total above ground dry biomass yield. The effect of different rates of nitrogen on teff harvest index was significant ($P \leq 0.05$). Harvest index decreased with increased rates of nitrogen. The highest harvest index was scored from the control plots received 32 kg UREA^{Stabil} ha^{-1} though statistically equal to plots treated with all rates except 48 kg UREA^{Stabil} ha^{-1} (Table 3). The lower biomass partitioning to grain production for higher UREA^{Stabil} rate might be because of application of higher nitrogen rates that led to relatively less shoot biomass growth as a result of late drought at the last growth (heading) stage. In line with this, Abdo (2009) and Abraha (2013) reported the highest teff harvest index for lower rate of nitrogen application.

Partial budget analysis

According to this study teff grain yield significantly affected by different UREA^{Stabil} rates and time of application. Grain yield was increased with increased N rates from 0 to 96 kg N ha^{-1} (Table 3). However, maximum grain yield was recorded form plots that were supplemented with 96 kg UREA^{Stabil} ha^{-1}which indicated that further increase in UREA^{Stabil} application beyond that level might still improve teff yield.

To assess the costs and benefits associated with the different treatments, the partial budget technique of CIMMYT (1988) was applied on grain 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, (CIMMT, 1988). As indicated in (Table 4) using 0 kg UREA^{Stabil} ha^{-1} in the area as a control plot, net revenue obtained in response to the rate 96 kg UREA^{Stabil} ha^{-1}was52142.23ETB. Biological results also indicated that grain yield is higher in response to 96 kg UREA^{Stabil}ha^{-1}.

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 96 kg UREA^{Stabil}ha^{-1} nitrogen fertilizer rate for teff crop is economically beneficial compared to the other nitrogen rates.

Table 4: Partial budget analysis of UREA^{Stabil} fertilizer for teff

Treatments	GY (kg/ha)	Adj.GY (10% less) (kg/ha)	(TR) [GY* 23.8] ETB (1)	SY(kg/ha)	Adj. SY (10% less) (kg/ha)	(TR) [GY*3.10] ETB (2)	Gross Revenue Sum (1+2)
0 (with no N fertilizer + basal)	1166.6	1049.94	24988.572	3598.4	3238.56	10039.536	35028.108
32 UREA^{Stabil} at planting + basal	1404.3	1263.87	30080.106	4055.1	3649.59	11313.729	41393.835
32 UREA^{Stabil} (1/3 by 2/3) + basal	1214.9	1093.41	26023.158	4308.6	3877.74	12020.994	38044.152
48 UREA^{Stabil} at planting + basal	1618	1456.2	34657.56	4525.2	4072.68	12625.308	47282.868
48 UREA^{Stabil} (1/3 by 2/3) + basal	1349.9	1214.91	28914.858	4430	3987	12359.7	41274.558
64 CU at planting + basal	1651.6	1486.44	35377.272	5100.5	4590.45	14230.395	49607.667
64 CU urea (1/3 by 2/3) + basal	1722.9	1550.61	36904.518	4751.4	4276.26	13256.406	50160.924
64 UREA^{Stabil} at planting + basal	1630.4	1467.36	34923.168	5100.3	4590.27	14229.837	49153.005
64 UREA^{Stabil} (1/3 by 2/3) + basal	1687	1518.3	36135.54	4723.2	4250.88	13177.728	49313.268
96 CU (1/3 by 2/3) + basal	1778.3	1600.47	38091.186	5219.6	4697.64	14562.684	52653.87
96 UREA^{Stabil} at planting + basal	1843.1	1658.79	39479.202	5688.9	5120.01	15872.031	55351.233
96 UREA^{Stabil} (1/3 by 2/3) + basal	1724.1	1551.69	36930.222	5220.3	4698.27	14564.637	51494.859

Table *contd'*…

Treatments	Gross Revenue (1+2)	Costs			Net Revenue [TR-TVC] (ETB)	MRR (ratio) [(Rt2-Rt1)/(Ct2-Ct1)]	MRR (%)
		fertilizer cost (ETB)	Transport & Application cost (ETB)	Total variable cost (TVC) (ETB)			
0 (with no N fertilizer + basal)	35028.11	0	0	0	35028.11	-	-
32 UREA^{Stabil} at planting + basal	41393.84	1010	60	1070	40323.84	4.95	494.9278
32 UREA^{Stabil} (1/3 by 2/3) + basal	38044.15	1010	90	1100	36944.15	D	-
48 UREA^{Stabil} at planting + basal	47282.87	1510	60	1570	45712.87	10.78	1077.807
48 UREA^{Stabil} (1/3 by 2/3) + basal	41274.56	1510	90	1600	39674.56	D	-
64 CU at planting + basal	49607.67	1741.43	120	1861.43	47746.24	6.98	697.7212
64 CU urea (1/3 by 2/3) + basal	50160.92	1741.43	180	1921.43	48239.49	8.22	822.095
64 UREA^{Stabil} at planting + basal	49153.01	2018	120	2138	47015.01	D	-
64 UREA^{Stabil} (1/3 by 2/3) + basal	49313.27	2018	180	2198	47115.27	D	-
96 CU (1/3 by 2/3) + basal	52653.87	2612.14	240	2852.14	49801.73	1.68	167.8542
96 UREA^{Stabil} at planting + basal	55351.23	3029	180	3209	52142.23	**6.56**	655.8603
96 UREA^{Stabil} (1/3 by 2/3) + basal	51494.86	3029	240	3269	48225.86	D	-

Where; D= dominated treatments

Conclusion and Recommendation

Application of different slow nitrogen releasing fertilizer rates for teff significantly ($P \leq 0.05$) affected most of the agronomic parameters tested such as days to 50% heading, days to 90% physiological maturity, plant height, panicle length, biomass yield, grain yield, straw yield, and harvest index. The highest mean grain yield of teff was obtained in response to the application of 96 kg N ha^{-1} rate from $UREA^{Stabil}$ with 676.5 and 191 kg ha^{-1} increments over the control treatment (0 kg N ha^{-1}) and that of recommended nitrogen (64kg N ha^{-1}), respectively. teff straw yield significantly enhanced with an increasing rate of N application from$UREA^{Stabil}$.

Based on the results of the study, it could be concluded that when growing teff fertilizer nitrogen input is needed to fulfill its growth. Slow nitrogen releasing fertilizer ($UREA^{Stabil}$) is important to; reduce the excessive input of nitrogen fertilizers, environmental pollution and for the soil to sustainably produce yield. Therefore, based on the results of this particular study it could be recommended that:-

- Nitrogen fertilizer at a rate of 96 kg N $ha^{-1}$from slow nitrogen releasing fertilizer ($UREA^{Stabil}$)for teff production should be used as a bench mark for further study on slow nitrogen releasing fertilizers for teff.
- Slow nitrogen releasing fertilizer rate should be studied and determined on site and crop specific conditions because the contribution these slow nitrogen releasing fertilizers to soil N and nitrogen requirement of crops may vary with varying nature of those crops and agro-ecologies.

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2.2. Effect of Rate and Time of Application of Slow Releasing N Fertilizer on Bread Wheat and Food Barley in Tigray

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Abstract

A field experiments were conducted to evaluate the effect of rate and time of slow releasing urea fertilizer on yield components and agronomic efficiency of wheat and barley. Wheat and barley experiments were carried out in Emba Alaje and Enda Mokoni, respectively. The treatments were five levels of slow releasing nitrogen fertilizer urea stabil (0, 32, 48, 64, and 96) and two levels of time of application (at planting and split application) with three replications in RCBD. Conventional urea at a rate of 64 kg N ha^{-1} was included as a positive control. The result revealed that, in Emba Alaje, the highest wheat grain yield was harvested from split application of urea stabil at a rate of 96 kg N ha^{-1} (4340 kg ha^{-1}). In Enda mokoni the highest barley grain yield was obtained from the application of conventional urea at a rate of 64 kg N ha^{-1}. The highest wheat agronomic efficiency was obtained from the application of urea stabil at a rate of 48 kg N ha^{-1} (21.5 kg kg^{-1}) in split application. The highest barley agronomic efficiency was found on plots treated with 48 kg N ha^{-1} (15.6 kg kg^{-1}) applied at planting in the form of slow releasing urea, which was urea stabil. At both sites, one kg of N application caused increase in grain yield by 21.5 kg and 15.6 kg at Emba Alaje and Enda mokoni, respectively. Either of slow releasing or conventional urea could be used for wheat and barley production at both sites.

Keywords: Wheat, Barley, Conventional urea, slow releasing urea, Agronomic efficiency

Introduction

In Ethiopia, for the last five decades Urea as a source of nitrogen and DAP as a source of phosphorus fertilizers were applied to obtain optimum harvest. Nitrogen (N) is often the most limiting nutrient for crop yield in many regions of the world. Nitrogen fertilizer is one of the main inputs for cereal production systems. The increase of agricultural food production worldwide over the past four decades has been associated with a 7-fold increase in the use of N fertilizers (Hirel et al 2007).

Availability of nitrogen applied as fertilizer to a crop depends not only on the rate but also on the nature of the N fertilizer, soil types and conditions, cropping system, management as well as on temperature and precipitation during the growing season (Przulj and Momcilovic 2001). Highly soluble N fertilizers, like urea may be lost from the soil plant system through leaching, NH_3 volatilization, denitrification and immobilization or may be fixed on the soil colloids as NH_4-N form (Bock 1984). Urea has a major disadvantage in that considerable amounts of N can be lost through volatilization which might be resulted in very low N fertilizer use efficiency (Chen et al 2008). The N recovery by crops from the soluble N fertilizers such as urea is often as low as 30–40%, with a potentially high environmental cost associated with N losses via NH_3 volatilization, NO_3^- leaching and N_2O emission to the atmosphere (Zhou et al 2003).

Different mechanisms which can improve the nitrogen fertilizer use efficiency of crops include improved cropping system, soil and water management, use of appropriate N fertilizer and application rate. In addition, use of slow N releasing fertilizers, urease inhibitor, nitrification inhibitor, efficient species or genotypes, and disease, insects and weeds control are important to improve the N fertilizer use efficiency of crops (Fageria 2009). However, most of the management options, such as slow N releasing fertilizers, urease inhibitor and nitrification inhibitors are not being practiced in Ethiopia. For instance, slow nitrogen release urea fertilizers can increase nitrogen use efficiency through either slowing the release rate or by altering reactions that lead to losses (Kathrine 2011). $UREA^{stabil}$ is one of slow nitrogen releasing urea.

The nitrogenous fertilizer $UREA^{Stabil}$ is urea enriched with the inhibitor of urease NBPT (N-(nbutyl)- thiophosphoric triamide). It reduces losses due to volatilization, leaching and denitrification (Mraz 2007). Thus, appropriate source of N fertilizer, rate and time of application may improve N fertilizer use efficiency of crops. Therefore; this study was initiated to determine optimum slow releasing urea stable nitrogen fertilizer rate and time of application under balanced fertilizer for wheat and barley production

Materials and Methods

Description the study area

Field experiments were conducted in farmers' fields for barley and wheat in Enda Mokoni and Emba Alaje, respectively (Figure 1) in 2016 and 2018 main cropping seasons. The mean annual rainfall of Mekan calculated from 2008 to 2018 was 665.6mm. The annual rainfall of the area in 2018 was 673.4mm of which 410.9 mm was calculated for the period of June to September.

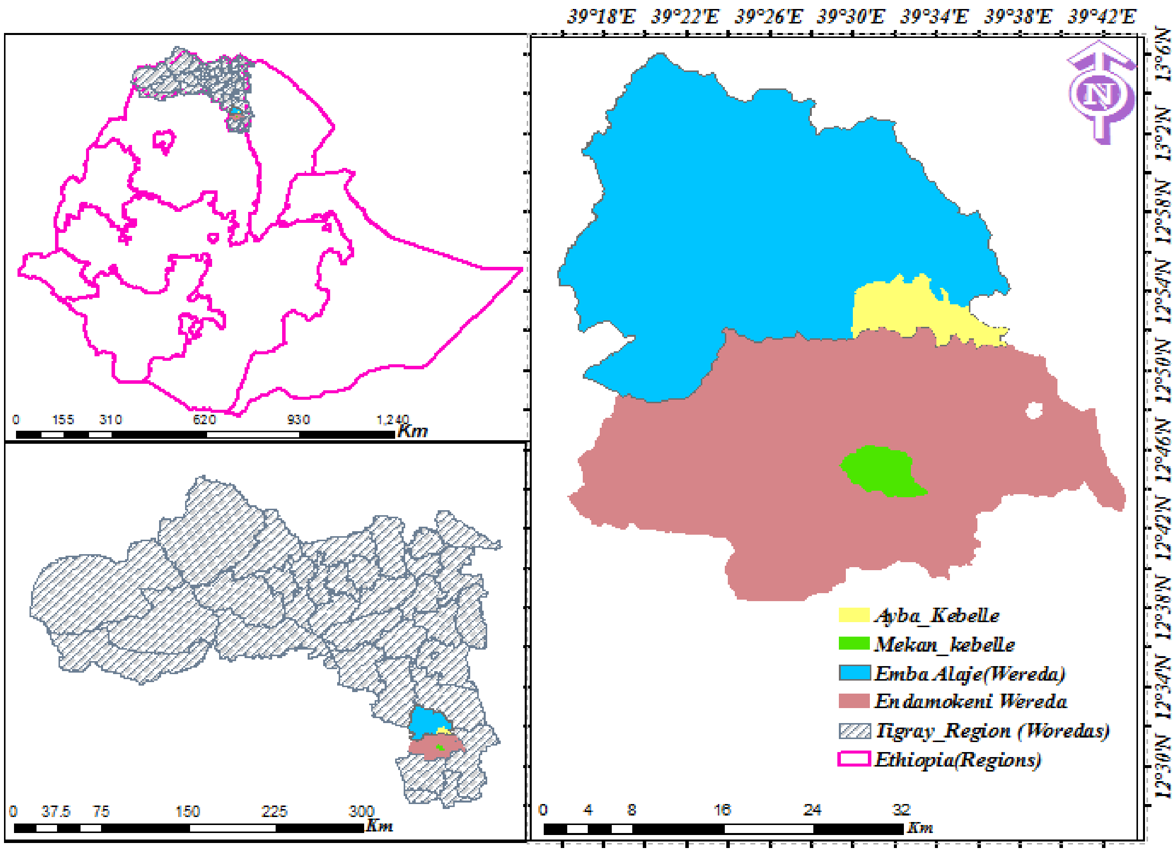

Figure 1. Study area map of Emba Alaje and Enda Mokoni, Tigray, Ethiopia

Experimental design and treatment

There were ten treatment and laid out in randomized complete block design with three replications at two farmers' field per year per district. Plot size was 3 m by 3 m. The spacing between rows, plots and replications were 20, 50 and 100 cm, respectively. Potassium in the form of murite potsash at a rate of 100 kg KCl ha^{-1} and phosphorous at a rate of 46 kg P_2O_5 ha^{-1} were uniformly applied to all plots. Prilled urea and urea stable were the sources of nitrogen fertilizer, Murite potash for potassium and triple supper-phosphate (TSP) for phosphorus fertilizer. Phosphorus and potassium fertilizers were applied in band at planting time and N was applied as per the treatment set-ups (Table 1). Wheat (king bird) and barley (HP 1307) improved varieties were used and planted in rows. Other agronomic practices were applied as per the recommendation of the crop.

Table 1. Treatment set up of the experiments

Treatment	Treatment description (N kg ha^{-1})	Treatment	Treatment description (N kg ha^{-1})
T1	0	T6	32 Urea Stabil split application
T2	32 Urea Stabil at planting	T7	48 Urea Stabil split application
T3	48 Urea Stabil at planting	T8	64 Urea Stabil split application
T4	64 Urea Stabil at planting	T9	96 Urea Stabil split application
T5	96 Urea Stabil at planting	T10	64 Conventional urea split application

Data collection

Soil data: Following the standard soil sampling procedures, representative composite soil samples (5-10 sub-samples) from each field was taken at a depth of 0-20 cm before planting and after harvesting. Each composite soil sample was analysed for pH, Electrical conductivity, cation exchange capacity, organic carbon, available phosphorous, total nitrogen and texture.

Agronomic parameters: 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.

Agronomic efficiency: Agronomic efficiency is the amount of additional yield obtained for each additional kg of nutrient applied (Fageria and Baligar 2001).

$$\text{Agronomic N use efficiency(kg kg}^{-1}) = \left(\frac{\text{Gf} - \text{GU}}{\text{Na}}\right)$$

Where;

Gf is the grain yield in the fertilized plot (kg)

Gu is the grain yield in the unfertilized plot (kg)

Na is the quantity of N applied (kg)

Data analysis

The collected data were subjected to analysis of variance using the general linear model procedure (PROC GLM) of SAS statistical package version 9.3 (SAS Institute Cary, NC). The total variability for each trait was quantified using pooled analysis of variance over years using appropriate models. Means for the effects of N fertilizer treatments were compared using the MEANS statement with the least significant difference (LSD) test at the 5% level (Gomez and Gomez 1984).

Results and Discussion

Before planting soil physicochemical 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 soils of ofla was slightly acidic at both sites. The organic carbon content of soils of the experimental sites was low low (Tekalign 1991). The total nitrogen content at both sites were low. Available phosphorous (Olsen P) was medium (Olsen 1954) and CEC was medium at both sites (Landon 1991).

Table 2. Soil physicochemical properties of the study sites in Emba Alaje and Enda Mokoni

Parameters	Enda Mokoni		Emba Alaje	
	2016	2018	2016	2018
pH water (1:2.5)	6.74	7.12	6.79	7.3
EC water (1:2.5), dS $m^{-}1$	0.1	0.18	0.105	0.12
Organic carbon (%)	1.52	1.23	2.021	1.92
Total N (%)	0.134	0.168	0.206	0.186
P-Olsen (mg kg-1)	23.6	34.07	24.8	14.2
CEC (meq/100 gm soil)	36.17	36.4	41	38.6
Clay (%)	26	30	18	18
Silt (%)	28	28	26	24
Sand (%)	46	42	56	58
Textural class	Sandy clay loam	Clay loam	Sandy loam	Sandy loam

Yield and yield components

Application of different rates and time of application of slow releasing nitrogen fertilizer influenced yield and yield components of wheat in Emba Alaje (Table 3). The analysis of variance revealed that plant height (0.021) and spike length (<0.0001) were significantly affected by rates, sources and time of application of nitrogen at Emba Alaje. The highest plant height was recorded through the application of 48 kg N ha^{-1} in the form of urea stabil applied at planting.

Table 3. Effect of urea stable on yield component of wheat grown at Ayba in Emba Alaje district combined over years (2016 and 2018)

Treatments	Emba Alaje				
	Two Year Combined analysis				
	Plant H (cm)	Spike L (cm)	Grain Yield kg ha^{-1}	Straw Yield kg ha^{-1}	Harvest Index (%)
0	79.8ab	7.9d	3106.2b	4119.5	0.43ab
32 US at plating	82.1ab	8.0cd	3524.1a	5044.2	0.44a
48 US at planting	84.4a	8.5ab	3867.1a	5379.4	0.44a
64 US at planting	83.2a	8.7a	4182.4a	5202.3	0.44a
96 US at planting	81.2ab	8.4abcd	4270.9a	5447.1	0.436ab
32 US split	81.6ab	8.1bcd	3701.8ab	4837.1	0.430ab
48 US split	78.4b	8.0d	4140.5ab	4964.7	0.436ab
64 US split	80.0ab	8.09bcd	4251.2ab	4866.2	0.41b
96 US split	80.4ab	8.6a	4340.2a	5325.1	0.44a
64 CU split	83.1ab	8.5abc	3923.5ab	5159.8	0.42ab
LSD (0.05)	4.67	0.474	838.25	NS	0.0215
CV (%)	4.9	4.87	18.2	15.58	4.21
P Value	0.021	<0.0001	0.05	0.259	0.047
Year	<0.0001	<0.0001	0.103	0.062	0.69
Trt*Year	0.7811	0.0045	0.074	0.429	0.019

Results showed that application of different rates and time of application of slow releasing nitrogen fertilizer had no statistically significant difference on straw yields of wheat in Emba Alaje. Except in the control plots grain yield was statistically the same on plots received nitrogen treatments and at different time of application. Application of urea stable in split application yields better than applying at planting.

Combined analysis over years showed no significant differences in spike length, grain yield, straw yield and harvest index except in plant height which was highly significant ($P< 0.01$) at Enda mokoni (Table 4). Highest plant height was recorded when 64 kg N ha^{-1} was applied showing 13.4% increment over the control but the differences were not statistically significant with the results of most treatments other than the control. Although the grain and straw analysis results showed statistically non-significant differences, higher grain and straw yields were obtained at the rate of 64 kg N ha^{-1} conventional urea with split application (Table 4).

Table 4. Effect of urea stable on yield and growth parameters of barley grown at Mekan in Enda mekoni district combined over years (2016& 2018)

Treatment (kg ha^{-1})	PH (cm)	SL (cm)	GY (kg ha^{-1})	SY(kg ha^{-1})	HI
0	84.42c	5.4867	3229.7	3181.4	0.489
32 US at planting	93.95ab	6.1333	3414	4333.5	0.4756
48 US at planting	96.93a	6.15	3978.6	4188.1	0.4825
64 US at planting	95.53ab	6.0333	3734	3963.2	0.4799
96 US at planting	95.72a	6.0333	3777.9	4427.7	0.458
32 US split application	92.60ab	6.1	3302	3767.6	0.502
48 US split application	89.90bc	6.2	3606.5	3779.7	0.4856
64 US split application	92.82ab	6.2	4095.7	4190.4	0.4883
96 US split application	93.42ab	6.2333	3908.6	3996.9	0.4943
64 CU split application	96.93a	6.7667	4149.5	4436.6	0.4835
LSD	5.7183	NS	NS	NS	NS
CV	5.09	8.87	19.99	20.85	4.40
P value	0.0061	0.1046	0.6551	0.3205	0.1246
Year 1	88.63b	6.467a	3204.0b	3819.9b	0.511a
Year 2	97.81a	5.80b	4478.0a	4233.1a	0.457b
LSD	2.8972	0.2834	411.70	403.86	0.0143
CV	5.77	8.58	19.90	18.62	5.48
P value	0.0000	0.0001	0.0000	0.0454	0.0000
P value of Year*Trt.	0.0167	0.2802	0.5005	0.3344	0.0000

* : US = Urea stabil, CU = Conventional urea, LSD = Least significant difference, CV = Coefficient of variation, PL = Plant height, SL = Spike length, GY = Grain yield, SY = Straw yield, Trt.= treatment and HI = Harvest index

Agronomic efficiency of wheat and barley to nitrogen rate and time of application

In Emba Alaje, the highest and lowest agronomic efficiency were obtained at 48 kg N ha^{-1} (21.5 kg kg^{-1}) in the form of urea stabil in split application and 96 kg N ha^{-1} (12.13 kg kg^{-1}) as UREA^{Stabil} at planting, respectively (Table 5). Therefore, one kg of N application caused increase in grain yield by 21.5 kg from plots treated with 48 kg N ha^{-1} in the form of urea stabil. In Enda Mokoni, the highest agronomic efficiency was found on plots received 48 kg N ha^{-1} in the form of urea stabil in split application (Table 5).

Table 5. Agronomic Efficiency of wheat to different rates of slow releasing nitrogen fertilizer

Nitrogen rate (kg/ha)	AEN Barley Emba Alaje (kg kg^{-1})	AEN wheat Enda mokoni (kg kg^{-1})
0		-
32 US at planting	13.05938	5.759375
48 US at planting	15.85208	15.60208
64 US at planting	16.81563	7.879688
96 US at planting	12.13229	5.710417
32 US split application	18.6125	2.259375
48 US split application	21.54792	7.85
64 US split application	17.89063	13.53125
96 US split application	12.85417	7.071875
64 CU split application	12.77031	14.37188

Conclusion and Recommendation

Applications of slow releasing urea and prilled urea significantly influenced growth parameters and yields of wheat, but not barley. The highest wheat grain yield was harvested from the application of 96 kg N ha^{-1} in the form of slow releasing urea in split application in Emba Alaje and the highest barley yield was obtained from the application of conventional urea in Enda Mokoni. Agronomic efficiency was also influenced by the application of slow releasing urea fertilizer at both sites. Most of the dependent variables analyzed showed no difference in barley response to the two forms of urea. Farmers can use either urea stable or conventional urea in the study areas.

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2.3. Evaluation of Different Forms of Urea Fertilizer on Yield and Yield Performance of Bread Wheat in Tigray, Ethiopia

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Abstract

A field experiment was carried out to evaluate four forms of urea (prilled urea, super granular urea, urea stabil and granular urea) and time of application of urea on yield and yield components of wheat. The treatments were arranged in split plot design. The main plot was time of application (at planting and split application) and subplot was forms of urea (prilled urea, super granular urea, urea stabil and granular urea) at recommended rate of 64 kg N ha^{-1}. Before planting soil samples were collected and analyzed following the standard procedure. Soil analysis result revealed that organic carbon (0.998 and 0.928) and total nitrogen (0.099 and 0.071) content were low at both sites. Application of different urea forms and time of application were statistically significant on yields of wheat at both sites. In Vertisols, the highest grain (3576.3 kg/ha) and straw yield (4483 kg/ha) was harvested from plots received urea stabil. But in Cambisols the highest grain (5103.1 kg/ha) and straw yield (5895.5 kg/ha) was obtained on plots treated with prilled urea (conventional urea). The lowest grain and straw yield was recorded on plots treated with super granular urea at both sites. Split application of urea was the better method than at planting application at both sites. Urea stabil, prilled urea and granular urea can be used as a nitrogen source of fertilizer for wheat production, but super granular urea is less efficient for cereals. Further study should be done on solubility of urea forms and in improving nitrogen use efficiency on different crops.

Keywords: Urea forms, Super granular urea, Wheat, Yield, Time of application

Introduction

Nitrogen (N) is often the most limiting nutrient for crop yield in many regions of the world (Hirel et al 2007). Availability of nitrogen applied as fertilizer to crop depends not only on the rate but also on the source of the N fertilizer, soil types and conditions, cropping system, management as well as on temperature and precipitation during the growing season (Przulj and Momcilovic 2001). Highly soluble N fertilizers like urea may be lost from the soil plant system through leaching, NH_3 volatilization, de-nitrification and immobilization or may be fixed on the soil colloids as NH_4-N form (Bock 1984). Then, yield and nitrogen fertilizer use efficiency of crops becomes low.

There are different mechanisms to improve the yield and nitrogen use efficiency. Cropping system, soil and water management, use of right source, rate, time of application and placement of N fertilizer are among the main management options to increase yield and N use efficiency (Fageria 2009). The use of different forms of urea may be one solution to boost up the yields and nitrogen use efficiency of cereals. Urea stabil, pirrled urea, granular urea and super granular urea are among different forms of urea. Now a day's the Ethiopian government is importing granular urea as a source of nitrogen fertilizer. On the other hand, ureas stabil is one form of slow nitrogen releasing urea. The nitrogenous fertilizer urea stabil is urea enriched with the inhibitor of urease NBPT (N-(nbutyl)- thiophosphoric triamide) and reduces volatilization of urea (Mraz 2007).

Slow releasing urea stabil fertilizer had significant effect on yield and yield components of wheat (Sofonyas et al 2018). Super granular urea is the newly introduced nitrogen fertilizer in some parts of Ethiopia for crop production. It is bigger in size than other forms of urea. However, the effects of different forms of urea fertilizer on yield and yield components of wheat were not well investigated in Tigray. Therefore, this study was initiated to investigate effects of different forms of urea and time of application on yield and yield components of wheat at Ofla.

Materials and Methods

The experiment was carried out in southern zone of Tigray Ofla district (Figure 1). The experiment was laid out in split plot design with three replications in two farmer's field. The experiments were consisted of two factors. Main plot consists two levels of time of application (whole at planting and two time split) and sub plot consists of four forms of urea fertilizer (Periled /conventional, Granular urea, Urea stable, and super granular) urea at a rate of 64 kg N ha^{-1}. The other nutrients were applied at the recommended rate (46 P_2O_5, 60 K_2O, 15 S kg ha^{-1}) to all plots at planting). Wheat (king bird) improved variety was used and planted in rows. Other agronomic practices were applied as per the recommendation of the crop for all plots equally.

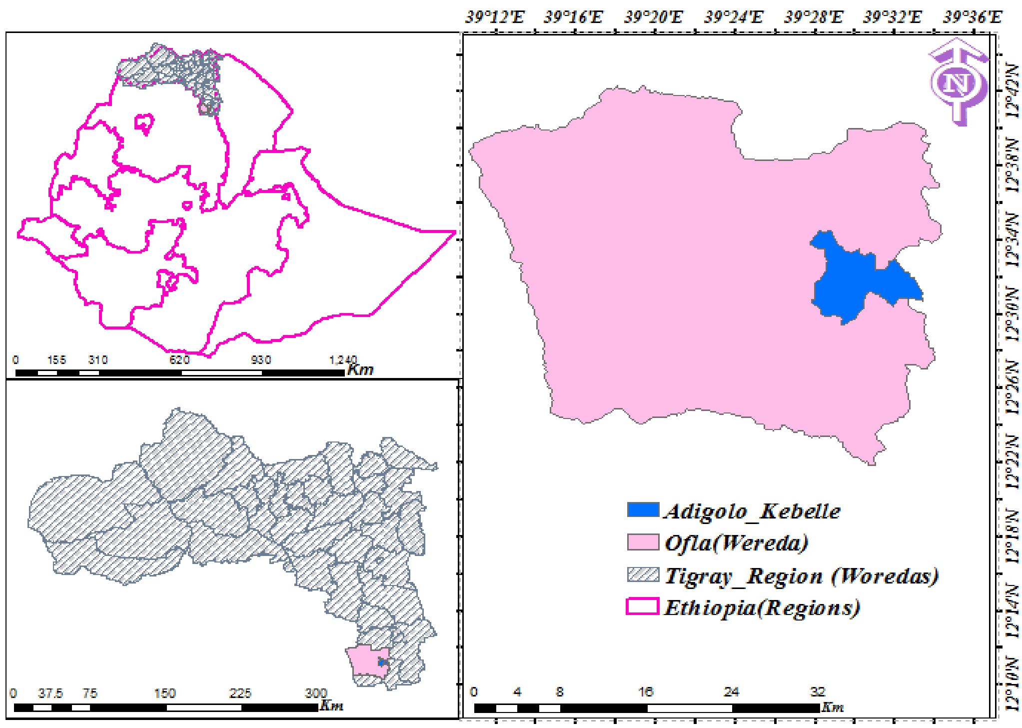

Figure 1. Study area map of Ofla district, Tigray, Ethiopia

Soil sampling and analysis

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, pH, EC, OC, 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 nitrogen 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 and CEC was determined by ammonium acetate method.

Agronomic 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) and mean separation was carried out following (Gomez and Gomez 1884).

Result and Discussion

Before planting soil physicochemical properties

Soil physicochemical properties of the study sites are indicated in Table 1. The texture class in the Vertisols and Cambisols was clay and clay loam respectively. According to Tekalign (1991) rating of soil pH, the pH of soils of Ofla was slightly acidic at both sites. The organic carbon content of soils of the experimental sites was low (Tekalign 1991). The total nitrogen content at both sites were low. Available phosphorous (Olsen P) was medium (Olsen 1954) and CEC was medium in Cambisols and high in Vertisols (Landon 1991).

Table 1. Soil physicochemical properties of experimental fields of urea form trials at Ofla

Parameters	Site 1 (Vertisols)	Site 2 (Cambisols)
pH_{water} (1:2.5)	6.09	6.03
Organic carbon (%)	0.998	0.928
Total N (%)	0.099	0.071
P-Olsen (mg kg^{-1})	8.9	9.2
CEC (meq/100 gm soil)	39.76	22.84
Clay (%)	46	32
Silt (%)	29	38
Sand (%)	25	30
Textural Class	Clay	Clay loam

Yield and yield components

Application of different forms of urea and time of application significantly influenced yield and yield components of wheat at both sites. Except number of effective tillers at field 2, growth parameters like plant height and spike length had no significant effect due to the application of forms of urea and time of application. Among four urea forms, significantly highest yield was achieved from the application of urea stabil, priled urea and granular urea, while the lowest grain and straw yield was obtained from the application of super granular urea at both soil types.

Table 2. Effect of urea form on wheat yield and yield components in Vertisols of Ofla (field 1)

Treatment	PH (cm)	SL (cm)	ET	GY(kg/ha)	SY (kg/ha)
Urea Super granule	75.3	6.2	3.50	2236.5 b	2903.5 b
Urea stabil	76.8	6.4	3.2	3576.3 a	4483.1 a
Prilled urea	76.6	6.16	3.3	3235.4 a	4295.2 a
Granular urea	76.3	6.13	3.56	3347.7 a	3961.7 a
LSD (0.05)	NS	NS	0.76	950.52	734.92
P Value	0.89	8.7	0.786	0.04	0.0015
Time of application					
M1 (at planting)	76.06	6.23	3.38	2753.2 b	3514.8 b
M2 (split application)	76.53	6.25	3.45	3444.7 a	4307.0 a
LSD (0.05)	NS	NS	NS	672.12	519.67
Time of application (P Value)	0.75	0.933	0.781	0.04	0.0052
Urea form*time of	NS	NS	NS	NS	NS
CV (%)	4.7	11.54	16.9	25.06	15.35

Table 3.1 Effect of urea form on wheat yield and yield component in Cambisols of Ofla (field 2)

Treatment	PH (cm)	SL (cm)	ET	GY(kg/ha)	SY (kg/ha)
Urea Super granule	79.4	6.56ab	3.4b	3366.2 b	4642.2 b
Urea stabil	79	6.73a	4.0a	4950.9 a	5590.5 ab
Prilled urea	77	6.16ab	3.4b	5103.1 a	5895.3 a
Granular urea	76.9	6.06b	3.3b	5002.4 a	5845.9 a
Urea form (P Value)	0.64	0.12	0.02	0.0004	NS
LSD (0.05)	NS	0.63	0.46	760.54	1099.4
Time of application					
M1 (at planting)	80.183a	6.60	3.48	4294.4 b	5009.8 b
M2 (split application)	76.0b	6.16	3.61	4916.9 a	5977.1 a
Time of application (P value)	0.02	0.059	0.39	0.026	0.017
LSD (0.05)	3.68	NS	NS	537.78	777.36
Urea form*time of Application	NS	NS	NS	NS	NS
CV (%)	5.45	8.19	10.6	13.49	16.35

The lowest biological yield on plots treated with super granular urea may be due to its bigger size and difficulty to apply to the whole farm uniformly. At field 1 (Vertisols), the highest grain (3576.3 kg ha^{-1}) and straw yield (4483 kg ha^{-1}) was harvested from the application of urea stabil. Sofonyas et al (2018) reported that slow releasing N fertilizer urea stabil significantly influenced grain and straw yields of wheat. But at field 2 (Cambisols) the highest grain (5103.1 kg ha^{-1}) and straw yield (5895.5 kg ha^{-1}) was obtained on plots treated with prilled urea (conventional urea). Split application of urea was the better method than at planting application of at both sites. This is highly related with the property of urea which can be lost from the soil plat system easily via leaching, volatilization, de-nitrification and immobilization. The interaction effect of urea form and time of application had no statistically significant effect at both sites.

Conclusion and Recommendation

The application of different form of urea had significant effect on growth parameters and yields of wheat in Vertisols and Cambisols of Ofla. Results depicted that application of urea stabil, prilled urea and granular urea had no significant effect on grain and straw yields of wheat at both soil types. The lowest yield was recorded from the application of super granular urea. This may be due to its bigger size and difficulty of application. Split application of urea fertilizer was better than applying the whole nitrogen at planting at both sites. Grain and straw yields were obtained from Cambisols than Vertisols. Application of super granular urea is not a best alternative to use as a source of urea fertilizer for wheat production. Urea Stabil, Granular urea and conventional urea (prilled urea) could be best alternatives to use as a source of N fertilizer for wheat production. Further study should be done on solubility of urea forms and in improving nitrogen use efficiency on different crops.

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2.4. Effect of Farmyard Manure and Residues of Lantana Camara on Yield and Yield Components of Teff at T/koraro District

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Abstract

Lantana camara is one of the most widely occurring shrubs that have shown alarming growth in recent years, in around shire, Axum and Adwa towns. Lantana camara makes available huge nitrogen rich succulent biomass, which has potential to be utilized as a substrate for organic recycling. However, research on comparative evaluation of lantana camara as a different manure and vermicompost for teff production has not been yet evaluated in the study area, northern Ethiopia. Hence, a field experiment was carried out for three years to evaluate the effect of different organic sources of fertilizers from lantana application on yield and yield components of teff at Beles kebele in T/koraro district of the Tigray Regional State. The experiment consists of seven treatments from lantana manure including control and laid out in a randomized complete block design with three replications. Surface soil samples were collected before planting and after harvesting wheat to analyze selected soil properties. The treatments significantly affected crop phenology, yield and yield components of teff as compared with control. Highest mean teff grain yield (1662.4kg/ha) was obtained in response to mixed compost application at (7t/ha). However, the partial budget analysis also shows that the highest marginal rate of return (232.42) was obtained from 4t/ha Lantana vermicompost at the study area. Therefore, application of 4t/ha lantana vermicompost is recommended as alternative sources of organic fertilizers for farmers in T/koraro district and other areas with similar agro-ecological conditions.

Keywords: Lantana manure, vermicompost, Biomass yield, Grain yield, Eisenia fetida

Introduction

The use of manure has generally declined on many farms due to increasing separation of crop and livestock production, cost of transporting manure, relatively low nutrient content, and increased availability of high synthetic fertilizers that usually provide a cheaper source per unit of nutrient than manure (Tripathi et al 1992). Despite these limitations, manure and other organic nutrient sources produced on or near a vegetable farm provide many benefits and should be beneficially utilized whenever possible. Manure and compost not only supply many nutrients for crop production, including micronutrients, but they are also valuable sources of organic matter (Vaidyaetal 2008). Increasing soil organic matter increases the water holding capacity of coarse-textured sandy soils, improves drainage in fine-textured clay soils, provides a source of slow release nutrients, reduces wind and water erosion and promotes growth of earthworms and other beneficial soil organisms (Flavel and Murphy 2006). Most vegetable crops return small amounts of crop residue to the soil, so manure, compost, and other organic amendments help to maintain soil organic matter levels.

*Lantana camara*is a multi-stem, deciduous, straggly branched shrub, with a high degree oftolerance for adverse environmental conditions. Its hardiness and high growth rate has made itone of the most aggressive biological invaders. It tends to form dense and impenetrable thicketsin degraded lands, pastures and edges of forests (Singh *et al* 2014). *Lantana camara* threatens habitats and native flora and fauna. It also infests and reduces economic viability of pastures, grazing lands, orchards and other tree crops. Direct incorporation of their green matter in soil causes poor germination of seed and reduction in crop yields.

However, the recycling of this weed as composted manures is the only way to avoid their nuisance; pollution effect and leading to their optimum use (Sharma et al 2008).Lantana camara makes available huge nitrogen rich moist biomass, which has potential to be utilized as a substrate for organic recycling. Its biomass has potential for utilization as organic manure has antimicrobial, insecticidal and medicinal properties (Montasser et al 2012). Similarly Lantana camara is one of the most widely occurring shrubs that have shown alarming growth in recent years in Shire, Axum and Adwa. The complete eradication of this weed without further use of its biomass is very difficult and costly. In addition the green matters of lantana camara have tremendous potential for being used as organic manures. Hence the objective of this study was to evaluate the effect of different rates of lantana camara on teff yield and yield components.

Material and Methods

Area description

The field experiment was conducted in 2014, 2015 and 2016 main cropping season under rain fed conditions at farmer's field in T/koraro, North western Zone of Tigray. T/koraro district is located on 38°18'45.099" E 14°3'17.535"N. The area has crop-dominated mixed crop-livestock farming system.

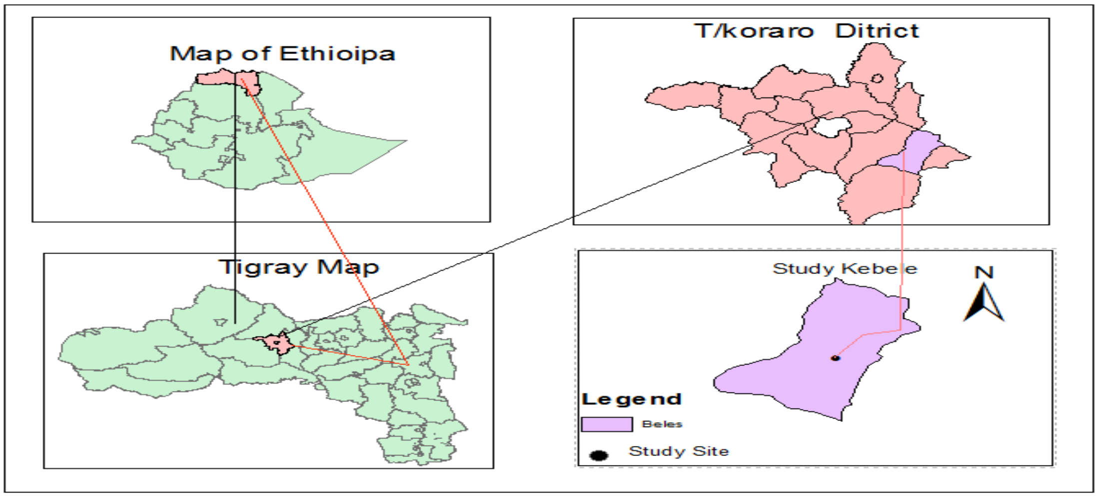

Figure 1. Map of the study area

Treatments, composting process and plot size

The experimental design was a randomized complete block design (RCBD) with seven treatments (Table 1) and two replicates implemented for three years (2014, 2015 and 2016 main cropping season).Conventional compost was prepared from a mixture of locally available weeds including Lantana camara , other leafs, as well as straws (teff, wheat, and legumes).

Table 1. Treatment setup of the research experiment

S.N.	Treatment code	Treatment description
1	Control	No application of supplemental nutrient
2	LVC	Application of lantana vermicompost at a rate of 4t/ha
3	DLM	Application of dry lantana manure at a rate of 7t/ha
4	MixCOM	Application of conventional compost/prepared from any locally available materials at 7t/ha of rate
5	FYM	Application farmyard manure at a rate 7t/ha
6	FLM	Application of fresh lantana manure at a rate of 7t/ha
7	LCOM	Application of lantana compost at a rate of 7t/ha

The Lantana weed was collected from different surrounding Shire town. To prepare lantana compost the lantana weeds was chopped into small pieces and dumped in 1m*2m*1m pit with the alternate layers of weed biomass, soil and dung. For the preparation of lantana vermicompost Eisenia fetida earthworms was inserted in to the pit and distributed uniformly. Lantana biomass was kept for drying as dry leaf manure (DLM). Similarly fresh lantana (FLM) weed was prepared by chopping freshly.

Soil sampling and analysis

Soil samples were collected from the experimental site at 0-20 cm depth using auger following zigzag technique. Accordingly, one composite soil sample was prepared. The soil samples were also air dried, crushed and allowed to pass through 0.5mm for Nitrogen and organic carbon analysis and 2 mm sieve for all other parameters. The collected soil sample before planting was analyzed for soil texture, pH, EC, organic carbon (OC), total N, available P, exchangeable K and CEC and results are presented in Table 2.

Table 2. Selected soil properties the study sites (sources own study)

Parameters	Selected soil properties of experimental sites					
	Year 1 (2007)		Year 2 (2008)		Year 3 (2009)	
	(Site1)	(Site2)	(Site1)	(Site2)	(Site1)	(Site2)
pH	6.34	6.81	6.66	6.56	6.34	6.56
EC(mmh)	0.4264	0.3338	0.21	0.321	0.220	0.244
Ava. P	9.202	8.821	1.847	2.35	6.988	4.016
% OC	0.902	0.902	0.558	0.452	0.673	0.966
% OM	1.556	1.556	0.962	0.778	1.161	1.665
CEC	40.6	45.6	45	42	47.80	47.00
% Sand	22	22	18	20	23	21
% Silt	37	37	26	27	29	22
% Clay	41	41	56	53	49	57
Tex. Class	clay	clay	clay	Clay	Clay	clay

Agronomic data collection

Agronomic data such as biomass yield, grain yield, days to 50% heading, days to 90% maturity (physiological maturity), plant height, panicle length and harvest index were collected at the appropriate growth stage of teff.

Statistical analysis

The data was subjected to the help of analysis of variance (ANNOVA) by following the standard procedure and by using SAS computer software analysis. After performing ANOVA the differences between the treatment means were compared by LSD test at 5% level of significance.

Results and Discussion

Yield parameters

Days to 50% heading: The application of different composts of lantana camara significantly at (P<0.05%) affects the days of maturity of teff crop as compared to control plots. The maximum number of days to reach 50% heading was observed on the control plot than the plots treated with different lantana manures. This may idicate the application of lantana manures may increase the matrix potential of the soil and short period of moisture content in the study area speed up heading of the crop at that period of time. This result is in line with findings of Sewnet (2005) who reported that early flowering with an increase in the rate of N application in rice. In contrast, Abraha (2013) reported that heading was significantly delayed at the highest N fertilizer rate compared to the lowest rate on teff, wheat and barley crops, respectively. This might be due tothe relative higher moisture content in his study area in which this can affect nutrient availability that can persist throughout the growth stage of the crop.

Days to 90% maturity: The application of different composts of lantana camara significantly affects (P<0.05% the days of maturity of teff crop as compared to control plots. The early maturity of plants on plots composts of lantana could be due to reduction of stress that causes forced maturity. In line with this study Mitiku et al (2014)have found that application of any rate of FYM, VC and NPK fertilizers hastened days toheading and maturity as compared to unfertilized plants.

Plant height and Head length: The application of different composts and manures of lantana had significantly influenced both plant height and head length at (P<0.05%). Thus tallest plant height were found from treatments that received Conventional compost plus recommended urea at 7t/ha which resulted in (117.36 cm) followed by lantana vermicompost (116.67cm) while the shortest plant (90.23 cm) was obtained from control plots. Similarly, longer head was obtained from conventional compost while shortest panicle was from control. Application of Lantana green or Lantana compost along with 60kgN/ha recorded yields statistically at par with the yield obtained by the application of 90kgN/ha alone (Chauhan and Thakur 2012).

Table 3.. Physiological parameters of teff crop under different lantana manure treatments

Treatment	Days to 50% Heading (days)	Days to 90 % Maturity (days)	Plant Height (cm)	Head length (cm)
Control	63.16[a]	109.417[a]	90.217[b]	40.233[b]
LVC	58.4167 [b]	106.250[ab]	116.675[a]	46.400[a]
DLM	60.75[ab]	107.333[ab]	112.650[a]	46.900[a]
MixCOM	58.5[b]	105.250[b]	117.367[a]	47.817[a]
FYM	58.75[b]	106.250[ab]	114.250[a]	46.017[a]
FLM	59.75[b]	106.083[ab]	114.700 [a]	46.25[a]
LCOM	60.25[b]	108.33[ab]	106.98[a]	43.55[ab]
Mean	59.94	106.98	110.40	45.31
LSD (P≤0.05)	2.57	3.55	10.95	5.54
CV (%)	3.46	4.08	8.00	9.86

Where LVC = Lantana vermi-compost DLM= Dry lantana manure MixCOM= mixed compost FYM= Farmyard manure FLM= fresh lantana manure LCOM= lantana compost

Biomass and grain yield

The application of different residues of lantana had significantly influenced biomass and grain yield at (P<0.05%). Thus the highest biomass (7313.4kg/ha) and grain yield (2057.8kg/ha) obtained from lantana vermicompost at 4t/ha followed by conventional compost at 7t/ha while the lowest biomass and grain was obtained from control plots (Table 4). Tef plants grown in plot received lantana vermicompost at 4t/ha ha^{-1} increased the grain yield by 132% over the control. Similar with this result Lantana manure when applied increased in grain and straw yield of maize and wheat crops (Mankotia et al 2006). (Psangita et al 2013) also reported that the average yield (kg/ha) of fresh vegetation of Trigonella was highest in vermicompost (11557 kg/ha) followed by conventional compost (10625 kg/ha), and Mixture of compost (10492 kg/ha), and Dry Lantana Manure 9323 kg/ha and lowest in Control (5961 kg/ha).

Table 4 Treatment effect of lantana camara manure on Teff biomass and grain yield.

Treatment	Biomass yield (kg/ha)	Grain yield (kg/ha)	Harvest Index
Control	3099.1[d]	885.4[e]	31.387
LVC	7313.4[a]	2057.8[a]	28.581
DLM	5988.1b[c]	1717.5[bc]	29.41
MixCOM	7147.9[ab]	2029.1[ab]	28.85
FYM	5031.5[c]	1364.1[d]	27.21
FLM	4887.9[c]	1392.8[d]	28.31
LCOM	5290.2[c]	1455.9[cd]	27.856
Mean	5536.871	1557.52	28.80
LSD (P≤0.05)	1175.7	318.61	NS
CV (%)	26.12	25.16	17.07

Where LVC = Lantana vermicompost DLM= Dry lantana manure MixCOM= mixed compost FYM= Farmyard manure FLM= fresh lantana manure LCOM= lantana compost

Partial budget analysis

To assess the costs and benefits associated with the different treatments, the partial budget technique of CIMMYT (1988) was applied to grain 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, 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, (CIMMT, 1988).

The highest marginal rate of return (MRR %) (467) was also recorded from the application of 4 t/ha lantana vermicompost at the study area (Tables 5). Therefore, application of 4t/ha lantana vermicompost is profitable and is recommended for farmers in T/koraro district and other areas with similar aggro-ecological conditions.

Table 5: Partial budget analysis of different sources of organic fertilizers from lantana, and farmyard manure.

Trt	Price per MD	Chopping cost	Transport and Application cost	Production cost	Total variable cost (TVC) [Birr]	Grain yield(Kg/ha)	Adj. yield (10% less) (kg ha-1)	Total Revenue (TR) [Grain yield*20]	Net Revenue [TR-TVC]	MRR ratio (tvc/tr)	MRR (%)
Control	0	0	0	0	0	885.4	796.86	15937.2	15937.2	0	0
LVC	60	720	1200	1800	3720	2057.8	1852.02	37040.4	33320.4	4.67	467
FYM	60	0	3360	1260	4620	1717.5	1545.75	30915	26295	D	D
FLM	60	2520	3360	0	5880	2029.1	1826.19	36523.8	30643.8	D	D
DLM	60	2520	3360	1260	7140	1364.1	1227.69	24553.8	17413.8	D	D
MixCOM	60	1260	3360	4200	8820	1392.8	1253.52	25070.4	16250.4	D	D
LCOM	60	2520	3360	8400	14280	1455.9	1310.31	26206.2	11926.2	D	D

Where LVC = Lantana vermicompost DLM= Dry lantana manure MixCOM= mixed compost FYM= Farmyard manure FLM= fresh lantana manure LCOM= lantana compost

Conclusion and Recommendation

The application of different manures of lantana had significantly influenced to biomass and grain yield of Teff. Thus, the highest biomass (7313.4kg/ha) and grain yield (2057.8kg/ha) obtained from lantana vermicompost at 4t/ha followed by conventional compost at 7t/ha while the lowest biomass and grain was obtained from control plots. While the lowest biomass and grain yield was obtained from control plots. At the teff plants grown in plot received 7t/ha ha^{-1} of conventional vermicompost increased the grain yield by 132% over the control. However, this highest grain yield was statistically par with the other rates of different organic lantana sources application. The highest marginal rate of return (MRR %)467was also recorded from the application of 4 t/ha of lantana Vermicompost. Therefore, application of 4 t/ha of lantana Vermicompost is economically profitable and is recommended for farmers at the district and other areas with similar aggro-ecological conditions.

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2.5. Effect of locally available straws and animal dung on growth and reproduction of earth worms (*Eisenia fetida*) species at T/koraro district

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Abstract

The experiment was aimed to evaluate the effect of different available straws and animals dung on growth and reproduction of Eisenia Fetida worms. There were 10 treatments representing different locally available sources. The experimentd was conducted at both dry and summar season. Data like worm population and weight after 14 daya and at maturity of the vermicompost were collected. Effect of the treatments on number and weight of worms after two weeks was highly significance at ($p \leq 0.05$). the treatments had significant ($p<0.05$) effect on days of maturity Thus Cow dung, lantana camara and donkey dung have relatively similar days of maturity indicating fast decomposition of the organic medias while rice and teff straw plus cow dung had late maturity. Effect of different treatment on weight and number of total worms at maturity was highly significant at ($p \leq 0.05$).. Effect of different available straws and animal dung on weight of total worms at maturity was highly significance at ($p \leq 0.05$). From the ANOVA analysis the highest total weight of worms was found in treatment with rice straw plus cow dung 398.24g followed by teff straw 375.07g. From this study, it is recommended that farmers that can have availability for rice and teff straw plus cow dung can use primarily as sources of organic feed for the worms. Similarly, farmers which have an access for lanatana camara can use as source of organic feed for Eisenia fetida composting worms.

Key words: Eisenia fetida; lantana camara; straw, dung

Introduction

Earthworms are the soil dwelling invertebrates, which have great agricultural importance. They influence the soil structure by ingestion, which leads to the breakdown of organic matter and its ejection as a surface or subsurface cast (Edwards and Lofty 1977). One of the most promising worms for vermicomposting is *Eisenia fetida* (Edwards 1988). Eisenia Fetida can use different solid wastes as foods, including legume litter, sewage sludge, activated sludge, rabbit manure, cattle manure, pig manure, and sheep manure (Kirchberger et al 2015).

So far, there are many studies and applications about earthworm-based disposal of agriculture wastes, including cattle manure which provides a more nutritious environment for earthworm composting. Numerous organic materials have been evaluated for growth and reproduction of earthworms as these materials directly affect the efficacy of vermicompost (Li et al 2016). Vermicompost, an organic fertilizer rich in NPK, micronutrients and beneficial soil microbes (nitrogen fixing and phosphate solubilizing bacteria and actinomycetes), is a sustainable alternative to chemical fertilizers, which is an excellent growth promoter and protector for crop plants (Chauhan and Singh 2012).

According to Xie et al (2016) the 60-day experiment of vermicomposting shows that 100% sludge is suitable for the growth and fecundity of earthworms, while the addition of CD into sludge significantly improved the worm biomass and reproduction, as it improved the environment for earthworm fecundity. Properly treating the organic waste fraction reduces the environmental impact by avoiding greenhouse gas emissions from landfills (Hoornweg and Bhada-Tata 2012). In most studies, animal dung is recognized as a suitable earthworm culture media, but other organic waste material as well as different animal dung has also proved successful. There was no study regarding the vermicomposting of organic sources from different straws and animal dung in the study area. The aim of this study was to evaluate the effect of different available straws and animal dung on growth and reproduction of Eisenia Fetida worms.

Materials and Methods

Description of the study area

Field experiment was conducted at Shire Soil Research Center office, T/koraro district. T/koraro district is one of the six districts of the North West Zone, is located with latitude and longitude of 14^0 6'N and 38^0 17'E respectively. The average district altitude is 1953 meters above sea level.

Treatments and experimental design

The treatments of the experiment was consists 1) Lantana camara + cow dung, 2) Teff straw + cow dung, 3) Rice straw+ cow dung, 4) Chicken manure + cow dung, 5) Cow Dung, 6) Donkey Dung, 7) Sheep manure, 8) Goat manure, 9) Soil and 10) Mixture of organic materials (1-8).

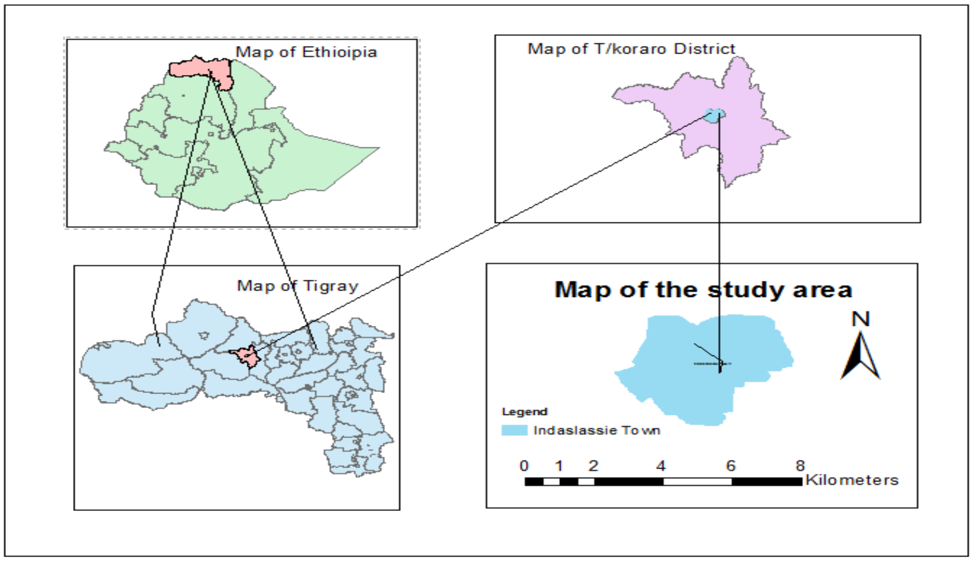

Figure: 1 Map of study area

Young *Eisenia fetida*, was collected and weigh from previously maintained worm bin and 250 worms per plastic was added. Twenty plastic containers (pots) with a diameter of 14 cm and depth 12 cm was prepared and were filled with weigh 5kg organic material from each treatment. The moisture content of wastes was adjusted to 70–80% during the study period by spraying adequate quantities of tap water. The wastes were turned over manually every day for 5 days in order to eliminate volatile toxic gases. After 5 days, 250 worms were introduced in each container. All containers were keeping in dark area at controlled ambient temperature. All the samples were dried on shade and sampled for laboratory analysis. All experiments were carried out in two replicates.

Data collection

During the study Biomass gain or loss, weight gain or loss, maturity date and mortality rate were collected after two weeks and at maturity days. The feed in the container was turned out, and earthworms and cocoons were separated from the feed by hand separation, after which they were counted. The worms were weighed without voiding their gut content. Corrections for gut content were not applied to any data in this study. After counting all earthworms and feed were returned to the respective container. No additional feed was added at any stage during the study period.

Data analysis

All experiments were carried out in two replicates and results were analyzed using SAS software Duncan's Multiple Range Test.

Result and Discussion

Treatment effect on number of worms after 14 days

Effect of different organic Medias on Number of worms after two weeks was statically significance at (p≤0.05). Even though there was significant difference, the number of worms after two weeks in all organic media was decreased. Maximum number of worms found in rice straw plus cow dung (285), donkey dung (255.5) and lanatana camara (238) in the first season. In the second season relatively greater number of worms after two weeks was obtained from teff straw and cow dung while the lowest number of worms was observed in the soil treatment. Sheep/goat manure showed continuous mortality after the replacement of medium may be due to its acidity in both seasons. According to the study of Siddique et al (2005) in sheep/goat manure and simple soil, no cocoon was observed, they showed no hatchling production.

Table 1. Number of worms and weight of total worms after 14 days under different treatments at dry season or winter

Organic wastes	Number of worms at initial	Initial weight of total worms	Number of worms after 14 days	Change in Number (%)	Weight of total worms after 14 days	Change in Weight (%)
Soil	250	69.435	126.50^{e}	-49.4	25.07^{d}	-63.88
Teff straw + cow dung	250	54.89	234.00^{c}	-6.4	153.23b	179.16
Rice straw + cow dung	250	58.77	285.00^{a}	14	136.86^{c}	132.88
Chicken waste + cow dung	250	49.765	0.00^{f}	-100	0.00^{e}	-100
Cow dung	250	52.88	208.00^{d}	-16.8	151.86^{b}	187.17
Donkey dung	250	77.25	255.50^{b}	2.2	171.86^{a}	122.47
Sheep waste	250	69.6	0.00^{f}	-100	0.00^{e}	-100
Goat waste	250	68.62	0.00^{f}	-100	0.00^{e}	-100
Lantana + cow dung	250	67.605	238.00^{c}	-4.8	179.45^{a}	165.43
Mixed	250	79.73	237.50^{c}	-5	173.79^{a}	117.97
Mean			158.45		99.21	
LSD (P≤0.05)			***		***	
CV (%)			2.47		6.44	

Effect on weight of total worms after 14 days

Effect of different organic Medias on weight of total worms after two weeks was statically significance at (P≤0.05). Hence Lanatana camara had large weight (179.45 gram) of worms relatively to all treatments followed by mixed and cow dung in the first season. However, in the second season greater weight of worms was found from mixed of treatments. Sheep/goat manure showed continuous mortality after the replacement of medium may be due to its acidity in both seasons. Highest biomass production of 25.7g earthworm/ week was recorded in cellulose substrate while the lowest value, 17.8g earthworm/week was recorded in soil substrate (Sogbesan 2006).

Table 2. Number and weight of total worms after 14 days under different treatments at Season 2 (rainy season or summer)

Organic wastes	Number of worms at initial	Initial weight of total worms	Number of worms after 14 days	Change in Number (%)	Weight of total worms after 14 days	Change in Weight (%)
Soil	250	69.25	37.50[f]	-85	3.33[f]	-95.19
Teff straw + cow dung	250	68.5	414.50[a]	65.8	144.82[b]	111.41
Rice straw + cow dung	250	82	343.00[b]	37.2	120.55[c]	47.01
Chicken waste + cow dung	250	81.5	0.00[g]	-100	0.00[f]	-100
Cow dung	250	64.3	243.00[c]	-2.8	156.66[b]	143.63
Donkey dung	250	61	138.50[d]	-44.6	66.88[e]	9.65
Sheep waste	250	59	0.00[g]	-100	0.00[f]	-100
Goat waste	250	62.5	0.00[g]	-100	0.00[f]	-100
Lantana + cow dung	250	64.2	106.50[e]	-57.4	91.23[d]	42.10
Mixed	250	70	232.50[c]	-7	186.79[a]	166.85
Mean			151.550		77.026	
LSD (P≤0.05)			***		***	
CV (%)			4.038		6.92	

Days to maturity of different straws and manures

Effect of different organic Medias on days to maturity was statically significance at (P≤0.05) on both seasons. Thus, Cow dung, lantana camara and donkey dung have relatively similar days of maturity indicating fast decomposition of the organic Medias while rice and teff straw plus cow dung have late maturity 112.5 and 116 days respectively indicating relatively slow decomposition rate in the first season. In the second season similar trend was observed on treatments with rice and teff straws. However, there is small number of days to maturity indicating fast decomposition rate in all treatments as compared to the first season. Sheep, goat and chiken manure showed continuous mortality after the replacement of medium may be due to its acidity in both seasons. In a trial comparing different substrates (San, 2001), found that it was not good to apply the earth worm culture in fresh manure when this came from pigs or poultry. Even when soil was mixed with the manure the growth of the earth worms was very little compared with using cattle manure.

Table 3:Days to maturity, number and weight of total worms at maturity under different treatments at dry season or winter

Treatment	Number of initial worms	Initial weight total worms	Days to maturity	Number of worms at maturity	Increase or decrease (%)	Weight of total worms at maturity	Increase or decrease (%)
Soil	250	69.435	0.00[d]	0.00[e]	-100	0.00[f]	-100
Teff + cow dung	250	54.89	116.00[a]	1773.50[b]	609.4	305.08[b]	455.80
Rice straw + cow dung	250	58.77	112.50[a]	2207.00[a]	782.8	348.24[a]	492.55
Chicken waste	250	49.765	0.00[d]	0.00[e]	-100	0.00[f]	-100
Cow dung	250	52.88	71.00[c]	203.00[d]	-18.8	127.22[e]	140.58
Donkey dung	250	77.25	73.00[c]	211.00[d]	-15.6	147.83[de]	91.3657
Sheep waste	250	69.6	0.00[d]	0.00[e]	-100	0.00[f]	-100
Goat waste	250	68.62	0.00[d]	0.00[e]	-100	0.00[f]	-100
Lantana + cow dung	250	67.605	71.50[c]	640.00[c]	156	213.80[c]	216.25
Mixed	250	79.73	91.50[b]	235.50[d]	-5.8	159.15[d]	99.61
Mean			53.55	554.73		130.13	
LSD (P≤0.05)			***	***		***	
CV (%)			3.89	5.59		8.42	

Effect on number of total worms at maturity

Effect of different organic Medias on weight of total worms at maturity was statically significance at (P≤0.05). After maturity the number of worms increase from 250 worms at initial to 2107 worms at maturity in a treatment that receive rice straw plus cow dung followed by teff straw plus cow dung with an increment of 250 worms to 1574 worms with percentage increment of 842.8 in the former and 629.2 in the later treatments in the first season.

Similarly, number of worms increase from 250 worms at initial to 2228 in treatments with teff straw plus cow dung as well as 250 worms was become 1664 in rice straw plus cow dung in the second season. The maximum number of mature worms in treatment 80% sheep manure + wheat straw 20% in the spring and in the 70% sheep manure + 15 % Glycyrrhizins glare + 15% Sawdust was implemented in the autumn to lowest number of manure worms indicated (Beyginiya et al 2013).

However, the lowest number Eisenia fetida was obtained from substrates of soil. According to the finding of (Loh et al 2003) an increase in the number of earthworms was observed during vermicomposting. They report that cocoon production in cattle manure was significantly higher ($P \leq 0.05$) than in goat manure. Sheep/goat manure showed continuous mortality after the replacement of medium may be due to its acidity in both seasons.

Table 4. Days to maturity, number and weight of total worms at maturity under different treatments at rainy season or summer

Treatment	Number of initial worms	Initial weight total worms	Days to maturity	Number of worms at maturity	Increase or decrease (%)	Weight of total worms at maturity	Increase or decrease (%)
Soil	250	69.25	91.50a	27.50^{e}	-89	1.38g	-98.01
Teff + cow dung	250	68.5	93.00a	2528.00^{b}	911.2	257.80^{b}	276.35
Rice straw + cow dung	250	82	95.50a	3326.50^{a}	1230.6	313.15^{a}	281.89
Chicken waste + cow dung	250	81.5	0.00c	0.00^{e}	-100	0.00^{g}	-100
Cow dung	250	64.3	69.50b	198.50^{d}	-20.6	136.165^{e}	111.75
Donkey dung	250	61	91.50a	136.35^{de}	-45.46	37.10^{f}	-39.18
Sheep waste	250	59	0.00c	0.00^{e}	-100	0.00^{g}	-100
Goat waste	250	62.5	0.00c	0.00^{e}	-100	0.00^{g}	-100
Lantana + cow dung	250	64.2	90.50a	418.00^{c}	67.2	148.30^{d}	130.99
Mixed	250	70	91.00a	251.00^{d}	0.4	170.20^{c}	143.14
Mean			62.25	688.58		106.41	
LSD ($P \leq 0.05$)			**	***		***	
CV (%)			3.95	8.34		4.16	

Effect on total weight of worms at maturity

Effect of different organic Medias on number of total worms after two weeks was statically significance at ($P \leq 0.05$) on both seasons. From the ANOVA analysis the highest total weight of worms was found in treatment with rice straw plus cow dung 398.24g followed by teff straw 375.07g. While the lowest weight of Eisefnia fetida was obtained from a container applied with soil. Highest total weight gain of 307.9 g kg of substrate was recorded from earthworm cultured in cellulose substrate while the lowest value, of 213.6 g kg was recorded for soil substrate (Sogbesan 2006).

Conclusion and Recommendation

Number and weight of total worms after 14 days was highest at rice and lantana camara in the first season, while it is high at rice and wheat straw in the second season. Slow decomposition rate was observed at teff and rice straw as compared to the rest of the treatments in the first season. Though small maturity dates recorded, similar trend in decomposition rate was observed at substrates of rice and teff in the second year. The highest number (2528.00) and (3326.50) of total worms at maturity was obtained from teff and rice respectively followed by lantana camaras in the first season. From the results obtained it can be conclude that there was continuous mortality of worms on Sheep/goat manure may be due to its acidity in both seasons while teff and rice plus cow dung were best for reproduction of Eisenia fetida followed by lanana weed.

It is also recommended that farmers that can have availability for rice and teff straw can use as sources of organic feed source for the worms.Similarly, farmers which have an access for lanatana camara can use as source of organic feed for Eisenia fetida composting worms. It is also noted that it is not recommended to use goat and sheep wastes for worm feed in addition to further research is needed on other straws which are not included on this study.

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2.6. Effect of Vermi-compost and NPS Fertilizer Rates on Yield and Yield Components of Tef[Eragrostistef (Zucc.) Trotter] at Tahtay Koraro

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Abstract

Tef is a stable crop in Ethiopia in which its yield is constrained by poor soil fertility management. Therefore, a field experiment was conducted for two consecutive years during 2016 and 2017 on clayey textural soil to assess the effect of vermicompost and inorganic fertilizer rates on yield and yield components of tef. Accordingly, field experiment with four levels of vermicompost (0, 2, 4 and 6 t ha^{-1}) and four levels of NPS (0, 100, 150 and 200 kg ha^{-1}) were arranged in randomized complete block design (RCBD) in a factorial combination with three replications. Tef variety, qunco was used as test crop. Analysis of the data revealed that highest grain yield (2269.80 kg ha^{-1}) was obtained from the treatment of 4 t vermicompost ha^{-1} +150 kg NPS ha^{-1}. To evaluate the feasibility of the treatments with a view of farmers' practices, a partial budget analysis was conducted on straw and grain yield of tef and accordingly the highest marginal rate of return 4184% was obtained from combined fertilization of 4 t vermicompost $ha^{-1}$and 150 kg NPS ha^{-1}. Therefore, based on the data obtained from this study application of 4 t vermicompost $ha^{-1}$and 150 kg NPS ha^{-1}will be recommended as profitable for the production of tef at Beles kebelle Tahtay Koraro district.

Keywords: Integrated Nutrient Management; NPS Fertilizer; Tef Yield; Vermicompost

Introduction

Tef is one of the most stable food crop originated and diversified in Ethiopia. It is highly preferred by Ethiopian people for consumption as food; since it is nutritionally rich and free of protein gluten (Ketema 1991; Merga M 2018). Moderately fertile clay and clay loam textural soils are ideal for tef growing. It can also withstand moderate water logged conditions (Anonymous 1994).

According CSA (2017/2018) area coverage of tef crop in Ethiopia was around 23.85% (3,023,283.50 ha) first and in term of grain yield production it was about17.26% (5,283,401.2 t) second after maize. Report of CSA (2017/2018) an area coverage and grain yield production of tef in Tigray region was approximately to 21.79% (167,748.72 ha) and 15.10% (257,906.10 t), respectively which was second only to sorghum in both productions. The national tef average grain yield was 1.75 t ha^{-1}which was higher than the regional tef yield(1.54 t ha^{-1}).

Farming systems in Ethiopia lack sustainability due to nutrient losses by soil erosion, lack of soil fertility restoring inputs and unbalanced nutrient use (Ajayi et al 2007; Hirpa et al 2009). Estimated essential plant nutrient loss in Africa wasapproximately 50 kg $ha^{-1}year^{-1}$(Janssen *et al* 1995). Inorganic fertilizers overcome soil fertility problems and responsible for increasing large part of world's food production (Sanchez and Leakey 1997). Increment of crop yield from 30 to 50% has resulted from application of commercial fertilizers (Stewart et al 2005). However, chemical fertilizers in effect, “kill” soil properties while organic fertilizers improve and sustain the soil (Goel and Duhan 2014). Excessive and inappropriate use of chemical fertilizers is the major cause of nutrient imbalance and degrading our soil (Mukhtar et al 2011). There is no absolute replacement of chemical fertilizers as the soils of Ethiopia are low in nutrients and organic matter. Nutrient recycling by use of organic manures is preferred to restore nutrient removed by crops (Jobe 2003).

Vermicompost is particularly good for farmers, consumers and ultimately for soil as it can be used as a resource for maximizing crop productivity on a sustainable basis and with more financial safe in comparison to these chemical fertilizers (Singh and Chauhan 2009). Vermicompost increase soil organic carbon, nitrates, phosphates, exchangeable calcium and some other nutrients for plants (Orozco et al 1996). Vermicompost is the recently organic fertilizer in supplementing chemical fertilizers for sustainable development of agriculture (Gupta 2003).

But, application of only organic manures inefficiently improves the yield per unit area (Jobe 2003). High cost of chemical fertilizers joinedwith its scarcity and non availability at the market during growing period of crops resulted in farmers fail to apply these fertilizers to their crop field in time. On the other hand, organic manure is readily available to the farmers and the price is also low (Alam et al 2007). In addition to that, applications of manures reduce the environmental pollution, but chemical fertilizers cause environmental pollution during manufacturing in the industry (Rathier and Frink 1989) and caused water eutrophication, which is resulted in increasing of unwanted species of aquatic plants and algae formation, degradation of water quality and water environment, bad water odor and dying of fish (Göksu et al 2003; Sönmez et al 2008).

Therefore, integrated management of plant nutrients can lessen this problem and can be suitable for any farming system and socio-economic conditions (Lamps 2000). Integrated plant nutrient management is the application of inorganic fertilizer in combination with organic fertilizer to maintain soil fertility and to balance nutrient supply in order to boost up the crop yield per unit area (Patra et al 2000; Aulakh et al 2008; Mahajan et al 2008; Roberts 2010). Organic matter is an imperative indicator of soil fertility Rahman et al (2007) by improving soil structure, nutrient exchange and maintain soil physical conditions (Becker et al 1995; Ayoub 1999). Organic matter also reduces the level of carbon dioxide in the atmosphere that contributes positively to climate change (Anon et al 2003). Therefore, the trial was aimed to investigate the effect of application rate of organic (vermicompost) and chemical fertilizer (nitrogen, phosphorus and sulfur) on the growth and yield of tef.

Materials and Methods

Area description

The field experiment was conducted for two consecutive years during 2016 and 2017 main cropping season under rain fed conditions at Shire Soil Research Center site in Beles kebelle Tahtay Koraro district, NorthWestern zone of Tigray regional state (Figure 1). Vertisols are the dominant soil types in the area. The study area is found in a semi-arid climatic zone and has mixed crop-livestock farming system. It received mono-modal erratic distribution of rainfall,with annual rainfalls of 1088.7 and 919.5 mm during the growing seasons of 2016 and 2017, respectively (Figure 2a). The average monthly temperatures were 20.7, 20.77^{o}C, respectively in the years of 2016 and 2017 (Figure 2b).

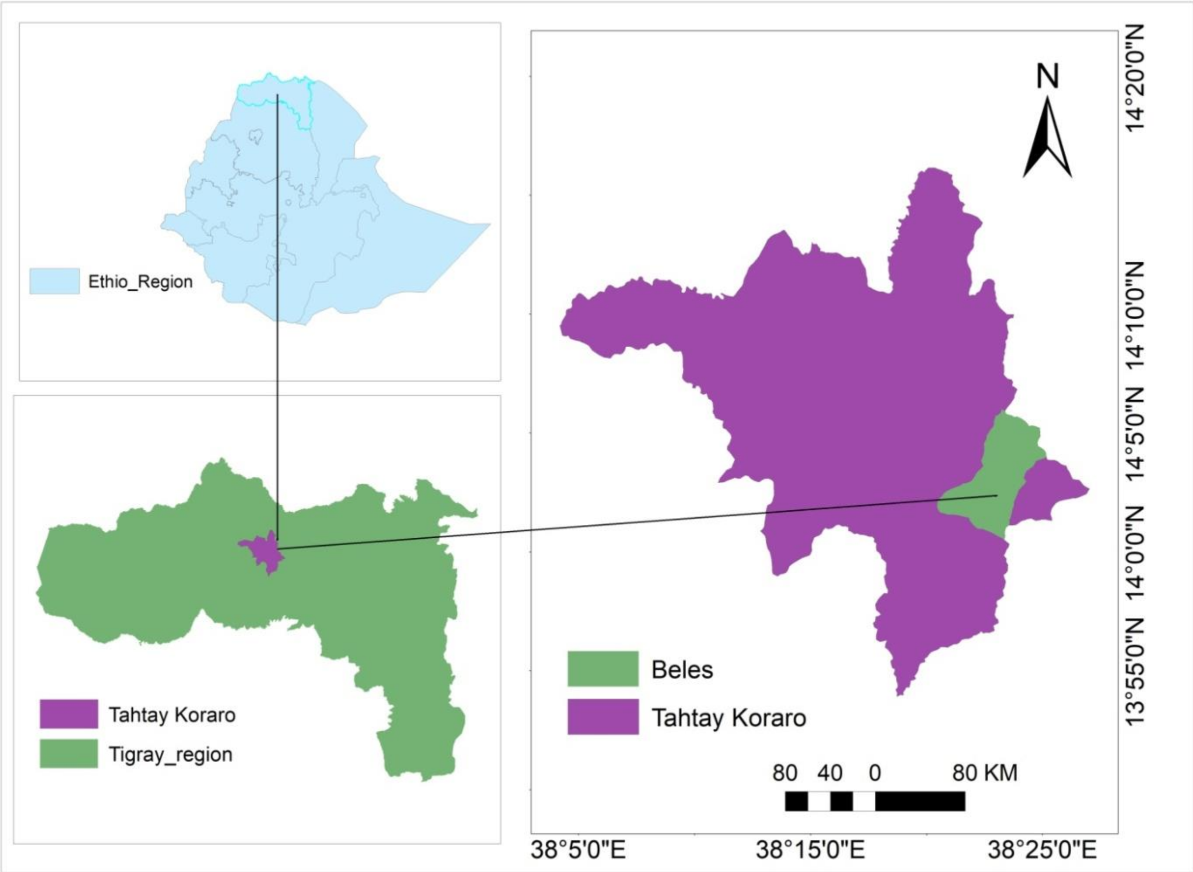

Figure 1. Location of the study area

Experimental design and treatments

The experiments were conducted at Shire Soil Research Center siteat Tahtay Koraro district. Permanent site and plots were used for conducting the experiment. The field experiments contain a total of sixteen (16) treatments. The treatments were four levels of Vermicompost (0, 2, 4, 6 t ha^{-1}) and four levels of new blended fertilizer (NPS) (0, 100, 150 and 200 kg ha^{-1}). The treatments were arranged in factorial arrangement and were laid out in RCBD with three replications. The plot size was 3 m*4 m (12 m^2) and the net harvested plot size area was 10.4 m^2. The spacing between rows, plots and replications was 0.2 m, 1 m and 1.5 m, respectively. Zn and B fertilizers were applied foliarly for all treatments except control treatment as uniform before head initiation.

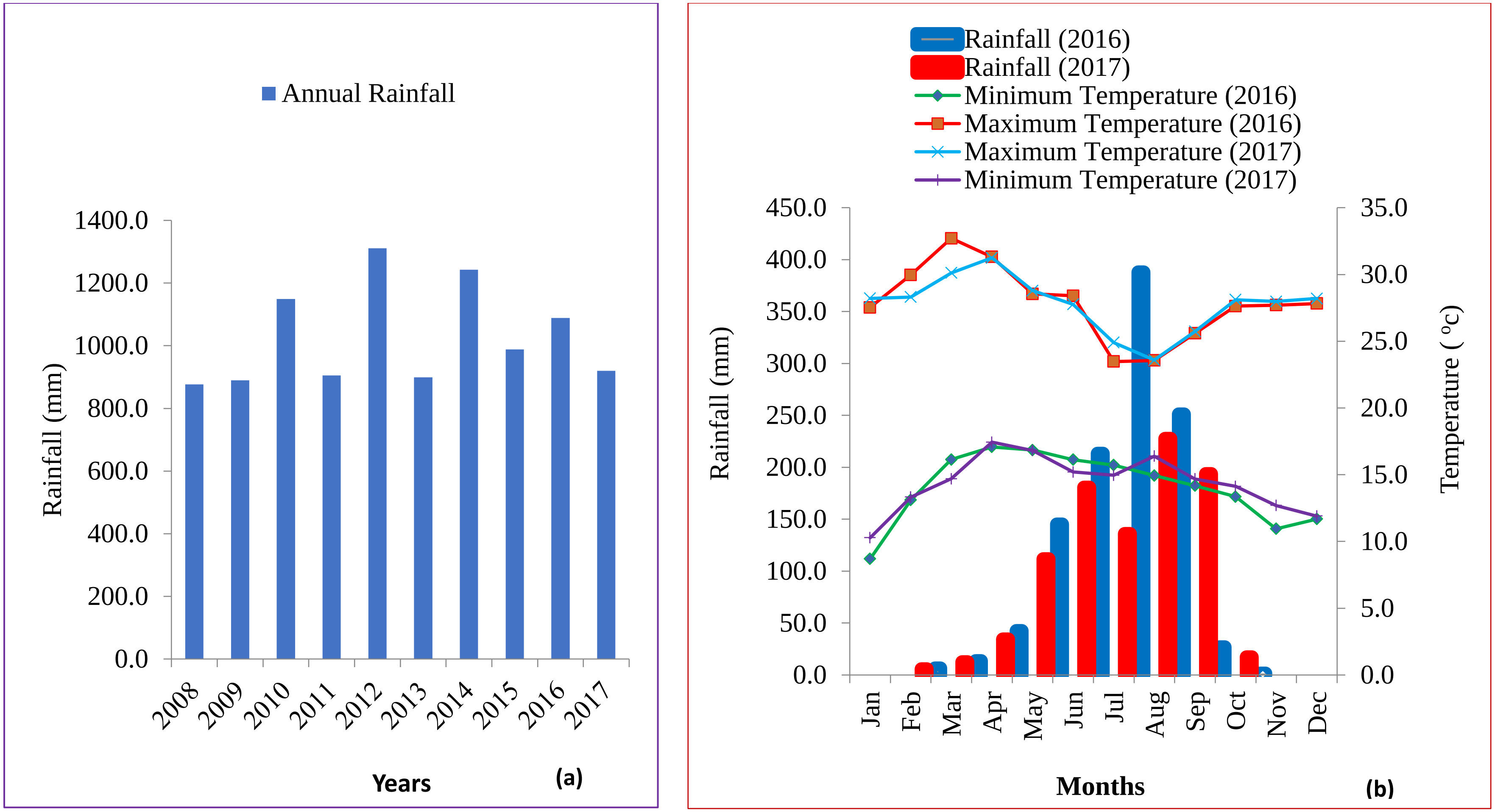

Figure 2. Ten years (2008-2017) annual rainfall (**a**), and monthly rainfall, maximum and minimum temperatures measured in the study area during growingseasons of 2016 and 2017(**b**) (**Sources**: National Metrology Agency of Ethiopia, Mekelle branch, 2019).

A full dose of blended fertilizer (NPS) was applied at planting time close to seed drilling line. The recommended seed rate of 10kg ha^{-1}quncho variety was used and sown by drilling method at each row. All recommended cultural practices (plowing, weeding, pesticides etc.) for tef crop was done as per the recommendation of the study area.

Soil and vermicompost samples analysis

Before planting surface composite soil sample was collected from the experimental site for site characterization and the soil sample was taken at a depth of 0-20 cm, auger was used for collecting the disturbed sample. The collected sample was properly labeled, packed and transported to the Shire Soil Research Center and analysed 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 a 1:2.5 soil to water ratio using a pH meter (Rhoades 1982). And electrical conductivity (EC) 1:2.5 soil to water suspension was measured according to the method described by (Jakson 1967). Organic carbon (%) was determined by method as described by (Walkely and Black 1934). Available P (ppm) was analyzed by employing the Olsen method Olsen et al (1954) using ascorbic acid as the reducing agent. Total nitrogen was measured using Kjedahl method as described by (Bremner and Mulvaney 1982). Exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}) and CEC in cmol (+) kg^{-1} soil was determined by ammonium acetate method. The laboratory soil result was revealed in Table 1.

Table 1. Soil physiochemical properties of the experimental site before planting

Parameters	Values	Ratings	References
Textural class	Clay		
OC (%)	0.550	Very low	Emerson (1991), Charman and Roper (2007)
OM (%)	0.95	Very low	Emerson (1991), Charman and Roper (2007)
Total N (%)	0.048	Low	Bruce and Rayment (1982)
pH	6.75	Neutral	Bruce and Rayment (1982)
ECe (dS/m)	2.32	Slightly saline	Richards (1954).
Ava. P (ppm)	2.65	Very low	Holford and Cullis (1985)
CEC [cmol(+)/kg]	34.3	High	Metson (1961)
Na[cmol(+)/kg]	0.21	Low	Metson (1961)
K [cmol(+)/kg]	0.52	Moderate	Metson (1961)
Mg [cmol(+)/kg]	14.91	Very high	Metson (1961)
Ca [cmol(+)/kg]	17.49	High	Metson (1961)

For conducting of the experiment organic fertilizer vermicompost was used as component of the treatments. Source of vermicompost was Lantana camara weed plant by the digestion of it by earth worms as worm cast. The organic carbon, N, P, K, pH and ECof vermicompost used in the experiment were determined following the standard method and presented in(Table 2).

Table 2. Chemical properties of vermicompost

Parameters	pH	EC(dS/m)	OC (%)	Total N (%)	Total P (ppm)	Total K (ppm)
Values	7.40	1.70	23.00	1.7	8200	11000

Agronomic data collection and analysis

Data collected for the experiment were days to 50% heading, days to 90% maturity, plant height (cm), panicle length (cm), biomass yield (kg ha^{-1}) and grain yield (kg ha^{-1}). Data were collected from plot and converted to hectare. Harvest index was calculated by considering the ratio of grain yield to biomass yield.

Data analysis

The collected data were subjected to statistical two way analysis of variance (ANOVA) using SAS version of 9.0 (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).

To evaluate the feasibility of different treatments partial budget analysis technique of CIMMYT (1988) was applied to straw and grain yield. The partial budget analysis was performed based on the field price of the crop with prices of 0.82$ kg^{-1} and 0.11$ kg^{-1} for grain and straw of tef, respectively. The partial budget analysis also included all the variable costs of fertilizers application, transportation, vermicompost production costs and prices of each fertilizer that vary for each treatment. 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 strawand grain yield has been adjusted to 10% lower than the actual yield obtained from the experimental plots to make the representative yield at the farmers' fields, (CIMMT 1988).

Result and Discussion

Days to 50% heading and 90% maturity

The interaction of vermicompost and NPS fertilizers and impact of NPS had brought significant effect (Table 3) on days to 50% heading. Tef crop that did receive high vermicompost and NPS headed earlier than those that receive no fertilizer or low fertilizer. Generally, all the treated plots excluding the unfertilized plot, 2 t vermicompost ha^{-1}, 4 t vermicompost ha^{-1} and 6 t ha^{-1} plus basal application of Zn and B to all these mentioned vermicompost amounts had a significantly lowest number of days to 50% heading. This may indicate the increased rate of chemical fertilizers increase the matrix potential of the soil and short period of moisture content in the study area speed up heading of the crop at that time.

Early headings of tef were perhaps due to highest rate of vermicompost and NPS fertilizers encourages the crop in early establishment, rapid growth and development. In line with this result, Mitiku et al (2014) had found that application of farmyard manure, vermicompost and nitrogen, phosphorus and potassium (NPK) fertilizers hastened days to heading and maturity as compared to unfertilized plots. This result is also in agreement with findings of Sewnet (2005) who reported of early flowering with an increased amount of N application in rice. In contrast, Abraha (2013) reported that heading was found significantly delayed at the highest N fertilizer rate when compared to the lowest dose of application on tef, wheat and barley crops.

It was observed that 90% days of maturity of tef crop were significantly affected by single levels of NPS fertilizer plus basal application of Zn and B fertilizers, but not by the combined application of vermicompost and NPS plus basal application of Zn and B fertilizers and single levels of vermicompost plus basal application of Zn and B fertilizers(Table 3).When plots were fertilized with only levels of NPS fertilizer there were significant effects. The extended days to maturity of Tef was observed at plots treated without NPS fertilizer. Early days to maturity of tef were recorded from application high levels of NPS fertilizers. This is probably due to the fact that chemical fertilizers enlarge the matrix potential of the soil and shorten period of moisture content in the soil. Application of optimum (NPS) fertilizers encouraged the early establishment, rapid growth and development. Similarly, Mitiku et al (2014) had articulated that fertilization of NPK fertilizers hastened days to maturity as compared to unfertilized plots.

Panicle length

The combined application of vermicompost and NPS fertilizers and main effect of NPS fertilizer significantly ($P<0.0001$) affected the panicle height of tef crop, but this was not so in case of sole application of vermicompost fertilizer (Table 4). Thus tallest panicle height (49.30 cm) was found from plots that received vermicompost at 6 t ha^{-1}+nil NPS plus basal applied Zn and B fertilizers. The shortest panicle height (35.27 cm) was obtained from control plot and from all plots those fertilized with interaction of nil vermicompost with the levels of NPS (100,150 and 200 kg ha^{-1}). In line with this finding, Fayera *et al* (2014) reported that the application of balanced fertilizer and efficient utilization of nutrients leads to high photosynthetic productivity and accumulation of high dry matter, which ultimately increases panicle length and grain yield.

Plant height

The effects of combined application of vermicompost and NPS fertilizers, and at their individual levels brought significance effect on plant height (Table 4). Highest plant height (120.27 cm) was obtained from application of vermicompost at 4 t ha^{-1}+200 kg NPS ha^{-1} plus basal applied Zn and B fertilizers. the shortest plant heights were observed in treatments plot fertilized with interaction of all levels of vermicompost with zero NPS fertilizer. The increment of plant height is due to sufficient supplies of balanced essential nutrients from vermicompost and NPS fertilizers. In agreement with this experiment, Kondappa et al (2009) observed that integrated nutrient management treated plots showed improved growth and yield of chilli. Alike, Degwale (2016) also observed that interacted application of vermicompost and NP fertilizers had resulted on increased plant height of onion. In the same way, Shrivastava et al (2018) studied that application of farmyard manure and vermicompost with inorganic fertilizers resulted in better cell division, cell expansion and enlargement that led to higher plant height of W. somniferaat different crop development stages. Likewise, Getachew (2009) reported that the use of organic manures in combination with mineral fertilizers maximized the plant height of barley.Kannan et al (2013) reported that integrated nutrient management had positive effect on maize height.

Table 3: Heading and maturity of tef under the effect of vermicompost and NPS fertilizers

VC(t ha^{-1})	NPS (kg ha^{-1})					NPS (kg ha^{-1})				
	0	100	150	200		0	100	150	200	
	DH (days)				Mean	PM (days)				Mean
0	70.67^{A}	61.0^{CD}	59.00^{D}	59.33^{D}	62.50	113.50	111.67	111.00	110.83	110.00
2	73.33^{A}	59.00^{D}	59.00^{D}	58.33^{D}	62.42	109.50	109.67	110.33	109.33	109.79
4	73.33^{A}	59.67^{D}	59.00^{D}	58.67^{D}	62.67	108.50	109.00	108.17	108.00	109.42
6	69.67^{B}	63.33^{C}	58.67^{D}	58.67^{D}	62.58	108.50	108.83	108.17	107.67	109.08
Mean	71.75^{A}	60.75^{B}	58.92^{C}	58.75^{C}		111.75^{A}	109.71^{B}	108.54^{B}	108.29^{B}	
CV (%)	4.48					3.18				
LSD(P=0.99) for VC	NS					LSD(P=0.81) for VC	NS			
LSD(P<0.0001) for NPS	1.6					LSD(P=0.0035) for NPS	2.00			
LSD(P<0.0001) for VC*NPS	3.23					LSD(P=0.30) for VC*NPS	NS			

Where, means followed by the same letters are not significantly different (P≤0.05), VC =vermicompost, NPS= (nitrogen, phosphorus, sulfur), DH = days to headings, PM = physiological maturity

Table 4: Panicle length and plant height of tef under the effect of vermicompost and NPS fertilizers

VC(t ha^{-1})	NPS (kg ha^{-1})					NPS (kg ha^{-1})				
	0	100	150	200		0	100	150	200	
	PL (cm				Mean	PH (cm)				Mean
0	70.67^{A}	61.0^{CD}	59.00^{D}	59.33^{D}	62.50	72.60^{E}	109.17^{ABC}	110.57^{ABC}	117.63^{AB}	102.49
2	73.33^{A}	59.00^{D}	59.00^{D}	58.33^{D}	62.42	75.30^{E}	109.83^{ABC}	108.70^{ABC}	112.90^{AB}	101.68
4	73.33^{A}	59.67^{D}	59.00^{D}	58.67^{D}	62.67	86.03^{DE}	98.00^{CD}	113.10^{AB}	120.27^{A}	104.35
6	69.67^{B}	63.33^{C}	58.67^{D}	58.67^{D}	62.58	84.27^{DE}	104.33^{BC}	109.77^{ABC}	120.03^{A}	104.60
Mean	71.75^{A}	60.75^{B}	58.92^{C}	58.75^{C}		79.55^{C}	105.33^{B}	110.53^{AB}	117.71^{A}	
CV (%)	12.99					12.48				
LSD(P=0.81) for VC	NS					LSD(P=0.83) for VC	NS			
LSD(P<0.0001) for NPS	3.27					LSD(P<0.0001) for NPS	7.40			
LSD(P<0.0001) for VC*NPS	6.54					LSD(P<0.0001) for VC*NPS	14.81			

Where, means followed by the same letters are not significantly different (P≤0.05), VC =vermicompost, NPS= (nitrogen, phosphorus, sulfur), PL = panicle length, PH = plant height

The growth, flowering and yields of field strawberries increased after applications of food wastes and paper waste vermicompost experimental soils, at rates of 2.5 or 5 ton ha^{-1}, supplemented with inorganic fertilizers (Arancon et al 2004). In contrast, Assefa et al (2016) found that interaction of compost and NP fertilizer did not show significant effect on plant height of tef.

Inversely, plots treated with sole levels of vermicompost showed no significance effect on plant height. The non-responsiveness of vermicompost might be due to slow release of nutrients. Similarly, with the current finding, Assefa et al (2016) found that treating of tef crop with compost did not reveal significance difference. Where as plots were fertilized with levels of NPS only significant variation amongst levels of NPS were shown. Plot received NPS at the dose of 200 kg ha^{-1} did show significant effect over plots treated with no fertilizer and plots received 100 kg ha^{-1} of NPS but not in cease of fertilizer of 150 kg NPS ha^{-1}.

Biomass yield

The combined application of vermicompost and NPS under balanced fertilizer significantly ($P<0.0001$) increased the biomass yield. Each single level of fertilizers of vermicompost and NPS had also significant effect on biomass yield of tef (Table 5). Therefore, the highest biomass yield (8150.40 kg ha^{-1}) was obtained from plots treated with 6ton ofvermicompost ha^{-1}+200 kg ha^{-1}NPS plus basal application of Zn and B fertilizers. However, it was not significantly different from using of 6 t vermicompost ha^{-1}+150 kg NPS ha^{-1}, 4 t vermicompost ha^{-1} + 150 kg NPS ha^{-1}, 4 t vermicompost ha^{-1}+200 kg NPS ha^{-1}, and 2 t vermicompost ha^{-1}+200 kg NPS ha^{-1}. It was clearly observed that with increased levels of the combination of the fertilizers there were increasing of biomass yields consistently in almost of the treatments.Devi et al (2011) reported that it might be due to adequate quantities and balanced proportions of plant nutrients in vermicompost supplied to the crop as per its need during the growth period resulting in a favorable increase in yield attributing characters.

In the same way, biomass yield was significantly affected by the main effect of NPS fertilizer under balanced fertilizer, and vermicompost levels. In general, at the level of 150 and 200kg ha^{-1} NPS plus basal of Zn and B fertilizers significantly higher biomass yield was found as compared to the nil and 100 kg ha^{-1} NPS fertilizer. The smallest biomass yield was measured from fertilization of nil NPS fertilizer. Similarly, highest biomass yield was also recorded from vermicompost application at the rate of 6 t vermicompost ha^{-1} as compared with the other three levels of vermicompost (0, 2, 4 t ha^{-1}). The least yield was obtained from nil and 2 t vermicompost ha^{-1}.

Grain yield

The analysis of the variance indicated that combined application of vermicompost and NPS and main effect vermicompost and NPS fertilizerssignificantly ($P<0.0001$) increased the grain yield (Table 5). Therefore, the highest grain yield (2269.80kg ha^{-1}) was obtained from plots treated with4 t vermicompostha^{-1}+150kg NPS ha^{-1}plus basal application of Zinc and Boron which increased over the control by 321.42%. The lowest (538.60 kg ha^{-1}) was found from control. The increase in grain yield due to interaction effects at this rate could be attributed to the positive effects of vermicompost in increasing the efficiency of synthetic fertilizer by preventing losses of nutrients and releasing of the nutrients within the growingperiod. In agreement with this result, Fayera et al (2014) postulated that fertilization witha balanced fertilizer leads to high photosynthetic efficiency and accumulation of high dry matter, which finally enhance grain yield of tef.

A study conducted by Manivannan et al (2009) stated that the increased growth and yield of the beans, may be due to the application of vermicompost which indirectly influences the physical conditions of the soil and support better aeration to the plant roots, absorption of water , induction of N, P and K exchange thereby resulting better growth of the plants. This is in agreement with reports of Bayu et al (2006) and Makinde and Ayoola (2010) who concluded that higher and sustainable crop yields are only possible with integrated use of mineral fertilizers and organic matter. Tilahun et al (2013) also verified that integrated fertilizers application gave the maximum grain yield compared to the control. Babbu et al (2015) also reported that the highest maize grain yield was in treatment having NPK with farm yard manure (FYM), whereas the lowest was in non-treated plots. Likewise, Quansah (2010) also indicated that the use of organic (household waste and poultry manure compost) and inorganic fertilizers (NP) increased maize grain yield separately. But the yields obtained by the combined treatments were significantly higher than their sole treatments. Assefa et al (2016) found that interaction of compost (2.5, 5, and 7.5 t ha^{-1}) and NP (64:46 kg ha^{-1}) fertilizer had significant effect on grain yield of tef.

Grain yield was significantly affected by the main effect of NPS fertilizer under balanced fertilizer. Generally, at the level of 150 and 200kg ha^{-1} NPS plus basal of Zn and B fertilizers significantly higher grain yield was found as compared to the nil and 100 kg ha^{-1} NPS fertilizer. From sole application of vermicompost highest yield was found from the rate of 6 t ha^{-1} as contrasted with nil and 2 t ha^{-1}, but not statistically significance than 4 t ha^{-1}.

Harvest index

Harvest index was significantly ($P<0.0001$) affected by the interactive effect of compost and NPS chemical fertilizer rates, and by main effect of NPS and vermicompost fertilizers (**Table 6**). The highest harvest index was measured from integrated use of 4 t vermicompost ha^{-1}+150 kg NPS ha^{-1} fertilizers as a result of higher conversation efficiency of dry matter to grain part of tef, but the smallest value was found from control. The highest harvest index was increased by 42.80% over the control treatment. The control treatment and highest combination of vermicompost and NPS fertilizers had smallest harvest index due to the vegetative growth of tef in control treatment remains sterile (unconverted the dry mass to the economic part), while in the highest combinations of vermicompost and NPS fertilizers vegetative part of tef continuously develop until the rainfall withdrew and not speed up to produce grain.

Though the augmentation was not consistent, the harvest index showed increasing trend with increasing of interaction of vermicompost and NPS fertilizers. The increase in harvest index with increasing rates of both compost and NPS fertilizer could be due to the fact that compost and NP fertilizer encouraged more vegetative growth and grain in a proportional way since the harvest index is the ratio of grain yield to dry biomass yield.In line to this result, Agegnehu et al (2014) reported that increased harvest index of rice with application of 15 t compost ha^{-1}, 83 kg N ha^{-1} and 50 kg superphosphate ha^{-1}over the control.

Table 5. Biomass and grain yield of tef under the effect of vermicompost and NPS fertilizers

VC (t ha^{-1})	NPS (kg ha^{-1}) 0	100	150	200	Mean	NPS (kg ha^{-1}) 0	100	150	200	Mean
	BY (kg ha^{-1})					GY (kg ha^{-1})				
0	2759.8^{G}	5141.0^{DE}	6488.9^{BC}	6451.7^{BCD}	5210.4^{C}	538.6^{H}	1301.7^{EF}	1520.2^{CDE}	1660.2^{BCD}	1255.17^{C}
2	3401.7^{FG}	5393.2^{CDE}	6145.3^{BCD}	7034.2^{AB}	5493.6^{C}	779.4^{GH}	1461.2^{DEF}	1651.5^{BCD}	1752.8^{BC}	1411.21^{B}
4	4379.5^{EF}	5427.4^{CDE}	7984.6^{A}	7140.2^{AB}	6232.9^{B}	909.4^{G}	1400.7^{DEF}	2269.8^{A}	1641.3^{BCD}	1555.29^{AB}
6	5940.6^{BCD}	6587.2^{BC}	7254.7^{AB}	8150.4^{A}	6983.2^{A}	1223.2^{F}	1571.5^{CDE}	1885.3^{B}	1669.9^{BCD}	1587.46^{A}
Mean	4120.4^{C}	5637.2^{B}	6968.4^{A}	7194.10^{A}		862.62^{D}	1433.8^{C}	1831.69^{A}	1681.03^{B}	
CV (%)			19.6					17.41		
LSD(P<0.0001) for VC			673.24			LSD(P<0.0001) for VC		145.27		
LSD(P<0.0001) for NPS			673.24			LSD(P<0.0001) for NPS		145.27		
LSD(P<0.0001) for VC*NPS			1346.5			LSD(P<0.0001) for VC*NPS		290.54		

Where, means followed by the same letters are not significantly different (P≤0.05), VC =vermicompost, NPS= (nitrogen, phosphorus, sulfur), BY = biomass yield, GY = grain yield

Table . Straw yield and harvest index of tef under the effect of vermicompost and NPS fertilizers

VC(t ha^{-1})	NPS (kg ha^{-1}) 0	100	150	200	Mean
	HI (%)				
0	20.12^{E}	25.5^{ABC}	23.38^{CDE}	26.2^{ABC}	23.8^{BC}
2	22.99^{CDE}	27.09^{AB}	26.94^{AB}	25.14^{BC}	25.54^{A}
4	21.07^{DE}	26.07^{ABC}	28.73^{A}	23.4^{CDE}	24.82^{AB}
6	21.32^{DE}	23.79^{BCD}	26.1^{ABC}	20.66^{DE}	22.97^{C}
Mean	21.37^{C}	25.62^{A}	26.29^{A}	23.85^{B}	
CV (%)			12.35		
LSD(P<0.0001) for VC	LSD(P=0.02) for VC			1.72	
LSD(P<0.0001) for NPS	LSD(P<0.0001) for NPS			1.72	
LSD(P<0.0001) for VC*NPS	LSD(P<0.0001) for VC*NPS			3.45	

Wheree, means followed by the same letters are not significantly different (P≤0.05), VC =vermicompost, NPS= (nitrogen, phosphorus, sulfur), SY =straw yield, HI=harvest index

In contrast to this result, Gebrekidan and Seyoum (2006) reported that harvest index constantly declined with increasing levels of applied N (150 kg ha^{-1}) though they found that harvest index increased with the application of P fertilizer at the rate of 26.4 kg ha^{-1} while further input beyond this optimum range resulted in highly significant reduction in rice crop. In addition, harvest index of tef crop increased significantly by the application of NPS fertilizer at the levels of 100, 150 and 200 kg ha-1over the nil NPS fertilizer, but there was no significance variation among the three levels of NPS (100, 150 and 200 kg ha^{-1}). Harvest index was also affected by the main effect of vermicompost where largest harvest index was measured from application 2 t vermicompost ha^{-1}plus basal application of Zn and B fertilizers but this was not statistically different from 4 t vermicompost ha^{-1} plus basal application of Zn and B fertilizers. The smallest harvest index was obtained from 6 t vermicompost ha^{-1} plus basal application of Zn and B fertilizers.

Partial budget analysis

As it was presented in Table**7** the net farm benefit was calculated taking all possible field variable costs and all benefits of straw and grain yields of tef. The maximum farm net benefits of \$2037.39/ha^{-1} were obtained from the interaction application of 4 t vermicompost $ha^{-1}$and 150 kg NPS ha^{-1} plus basal Zn and B fertilizers and this was followed by treatments of nil vermicompost + 100 kg NPS ha^{-1}, nil vermicompost + 150 kg NPS ha^{-1}, 2 t vermicompost ha^{-1} + nil NPS, 2 t vermicompost ha^{-1} + 200 kg NPS ha^{-1}, and nil vermicompost + 200 kg NPS ha^{-1}, respectively. In this study area partial budget analysis revealed that combined application 4 t vermicompost $ha^{-1}$and 150 kg NPS ha^{-1}, nil vermicompost and 100 kg NPS ha^{-1}, nil vermicompost and 150 kg NPS ha^{-1}, 2 t vermicompost ha^{-1} and nil NPS, 2 t vermicompost ha^{-1} and 200 kg NPS ha^{-1}, and nil vermicompost plus 200 kg NPS ha^{-1} had highest marginal rate of return (MRR) over the minimum acceptable rate of return(100%). From the above-mentioned treatments highest MRR% with value of 4184 was obtained from the combined application of 4 t vermicompost $ha^{-1}$and 150 kg NPS ha^{-1} plus basal Zn and B fertilizers. This value implies that with one \$ cost it was attained \$41.84 profit. Therefore, in Tahtay Koraro district integrated 4 t vermicompost ha^{-1} and150 kg NPS ha^{-1} can be used for the production of tef (quncho variety).

Table 7. Partial budget analysis of VC and NPS fertilizers effect on straw and grain yield of tef

TRT			BA (kgha^{-1})		ASY (kg ha^{-1})	ADSY (kg ha^{-1})	AGY (kg ha^{-1})	ADGY (kg ha^{-1})	TVC ($ ha^{-1})	TR ($ ha^{-1})	NB ($ ha^{-1})	MRR (%)
	VC (t ha^{-1})	NPS (kg ha^{-1})	Zn	B								
T 1	0	0	0	0	2221.20	1999.08	538.60	484.74	0.00	610.94	610.94	-
T 5	2	0	2	1	2622.40	2360.16	779.40	701.46	1220.00	826.56	784.07	407
T 2	0	100	2	1	3839.30	3455.37	1301.70	1171.53	1875.25	1327.95	1262.63	2097
T 9	4	0	2	1	3470.10	3123.09	909.40	818.46	2440.00	1004.30	919.32	D
T3	0	150	2	1	4968.70	4471.83	1520.20	1368.18	2812.88	1597.98	1500.01	727
T6	2	100	2	1	3931.90	3538.71	1461.20	1315.08	3095.25	1453.95	1346.14	D
T13	6	0	2	1	4717.40	4245.66	1223.20	1100.88	3660.00	1355.70	1228.22	D
T4	0	200	2	1	4791.50	4312.35	1660.20	1494.18	3750.50	1683.46	1552.82	162
T7	2	150	2	1	4493.80	4044.42	1651.50	1486.35	4032.88	1648.15	1507.68	D
T10	4	100	2	1	4026.60	3623.94	1400.70	1260.63	4315.25	1418.77	1268.47	D
T 8	2	200	2	1	5281.40	4753.26	1752.80	1577.52	4970.50	1798.99	1625.86	172
T11	4	150	2	1	5714.80	5143.32	2269.80	2042.82	5252.81	2220.35	2037.39	4184
T14	6	100	2	1	5015.60	4514.04	1571.50	1414.35	5535.25	1640.17	1447.37	D
T12	4	200	2	1	5498.90	4949.01	1641.30	1477.17	6190.50	1738.34	1522.72	D
T15	6	150	2	1	5369.40	4832.46	1885.30	1696.77	6472.88	1904.74	1679.28	D
T16	6	200	2	1	6480.60	5832.54	1669.90	1502.91	7410.50	1854.72	1596.60	D

Where, VC=vermicompost, TRT=treatment, BA=basal application, ASY=average straw yield, NPS= (nitrogen, phosphorus, sulfur), ADSY=adjusted straw yield, AGY=average grain yield, ADGY=adjusted grain yield, TVC=total variable cost, TR=total revenue, NB=net benefit, MRR=marginal rate of return, D=dominated treatment

NB:*yield adjustment=10%, price of tef straw =$0.11/kg^{-1}, price of tef grain =$0.82/kg^{-1}, minimum acceptable rate of return (MARR) =100% , , fertilizer transportation cost=$1.74 100 kg^{-1}; fertilizer application cost=4man/day/200 kg; NPS Fertilizer cost=$0.57/kg^{-1}; Zn Fertilizer cost=$1.01/kg^{-1}, B Fertilizer cost=$0.47/kg^{-1},VC production cost=$1.43/100kg^{-1}, VC application cost=6man/day/6tons,VC transportation cost=$0.35/100 kg^{-1}, labor cost/man/day=$3.48*

Conclusion and Recommendation

The results of these studies indicated that, combined application of vermicompost and NPS fertilizers significantly improved early heading and physiological maturity, panicle length, plant height, biomass yield, grain yield and harvest index of tef crop. Increased rate of combined application of vermicompost and NPS fertilizers enhanced tef crop to initiate early heading and early maturity in lesser number of days. The vegetative parameters like panicle length and plant height of tef crop were also significantly better by the higher rates of integrated application of vermicompost and NPS plus basal application of Zn and B fertilizers. The yield attributes like biomass and grain yieldwere as well significantly enhanced by the higher rates of combined application of vermicompost and NPS fertilizers, particularly, combined application of 4 t vermicompost ha^{-1} and 150 kg NPS ha^{-1}plus basal application of Zn and B fertilizers brought highest yield almost in all the yield attributes.

According to the partial budget analysis the highest marginal rate of return was attained from combined application of 4 t vermicompost $ha^{-1}$and 150 kg NPS ha^{-1} plus basal application of Zn and B fertilizers. Therefore, it can be concluded that 4 t vermicompost $ha^{-1}$and 150 kg NPS ha^{-1}plus basal application of Zn and B fertilizers from the economic standpoint, it is more profitable to farmers at Beles kebelle in Tahtay Koraro district. Therefore, based on the results of the study and the above conclusion, it can be recommended that; interactive application of 4 t vermicompost $ha^{-1}$and 150 kg NPS ha^{-1}plus basal application of Zn and B fertilizerscouldbe recommended in terms of economic return and productivity of tef (quncho variety) in the study area. This rate also can be used as a point of reference for additional study at vermicompost and NPS fertilizer for different tef varieties.

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2.7. Enhancing Water Use Efficiency of Maize Under Deficit Irrigation: The Case of Moisture Deficit Areas of Tigray, Ethiopia

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Abstract

The study was conducted to determine water use efficiency of maize under deficit irrigation practice without significant reduction in yield and identify sensitive crop growth stages. The experiment was conducted at the Alamata Agricultural Research Center experimental site. The experiment had six levels of irrigation water and laid out in randomized complete block design (RCBD) with three replications. Analysis was done to yield and water use efficiency of maize using R statistical software and the mean difference was estimated using the least significant difference (LSD) comparison. The highest grain (33.72qt/ha) and biomass yield (148.4qt/ha) was obtained from the 50% deficit irrigation at late growth. The maximum irrigation water use efficiency was obtained from both 50% deficit at all the four growth stages (0.5418 kg/ha) and at 50% deficit at late growth stage (0.446 kg/m3). And by comparing the grain yield obtained at the 50% deficit at late growth stage (33.72qt/ha) and grain yield obtained at 50% deficit at all growth stages (23.34 qt/ha), the 50% deficit at late growth stage shows better result. The 50% deficit of crop water requirement did not affect the yield components (plant height & number of cobs per plant) of maze. Therefore applying irrigation water by reducing the crop water requirement by 50% at the late growth stage has a significant contribution for sustainable and efficient irrigation water utilization at moisture deficient areas without a significant loss on grain and biomass yield.

Key words- Deficit irrigation, Maize, water use efficiency

Introduction

Maize (Zea Mays L.) is one of the most important food crops worldwide (Andy et.al., 2004). It has the highest average yield per hectare and is the third after wheat and rice in area and total production in the world (Andy et al 2004). In Ethiopia, maize is one of the leading food grains selected to assume a national commodity crop to support the food self-sufficiency program of the country (Abate et al 2015). Maize crop is fairly sensitive to water stress and excessive moisture stress. Water stress is the most limiting factor in maize production (Geerts and Raes 2009). Moisture stress during establishment kills young plants and reduces plant density. During the vegetative stage, it restricts leaf growth and expansion resulting in stunted growth.

With increasing moisture stress, the dry matter production of the crop decreases directly by decreasing cell division and enlargement and indirectly by reducing the rate of photosynthesis. Much of the past research on water stress on maize has consisted of full withholding of irrigation and conditions of severe water stress. At the same time, there is also indication that maize yield is just a linear function of seasonal Evapo-transpiration.

Deficit irrigation of maize distributed over the whole growing season might not always result in increasing crop water productivity. This is due to variation in sensitivity of different growth stages to water stress. It is essential to examine the effect of water stress at different growth stages on maize yield. Therefore, the study was aimed to determine water use efficiency of maize under deficit irrigation practice and to identify crop growth stages which can withstand water stress in the study area.

Material and Methods

Study area description

The field experiment was conducted at the Alamata Agricultural Research center experimental site located at Kara Adishabo Kebele, Raya Azebo district during the cropping season of 2017 and 2018. Particularly the experiment site is located at point of geographical reference 12.69^0 N latitude and 39.66^0 E longitude (Figure 1). The soil texture of the study site was found to be medium (loamy) type. Based on FAO recommendations a loam soil has a maximum infiltration rate 40 mm/day, total available soil moisture 290 mm/meter, maximum rooting depth 900 cm and initial soil moisture depletion 0 % TAM. The climatic condition of the research site is characterized as semi-arid. The mean minimum, maximum temperature and average annual precipitation of the study area is 16 ^{0}C, 29 ^{0}C and 546 mm respectively. The main physical and chemical characteristics of the soil in the study area are shown in Table 1. During irrigation application, water was applied to refill up to soil field capacity.

Experimental design

The experiment was conducted for 50% deficit irrigation of water requirement per each growing stages of the crop as treatments. There were six levels of irrigation water applications as treatments (Table 2). The experiment was laid out in randomized complete block design (RCBD) with three replications (Figure 2). Each treatment was laid out in 3.5m x 4m plot size. The distance between plots and the blocks were 1 and 2 meters respectively.

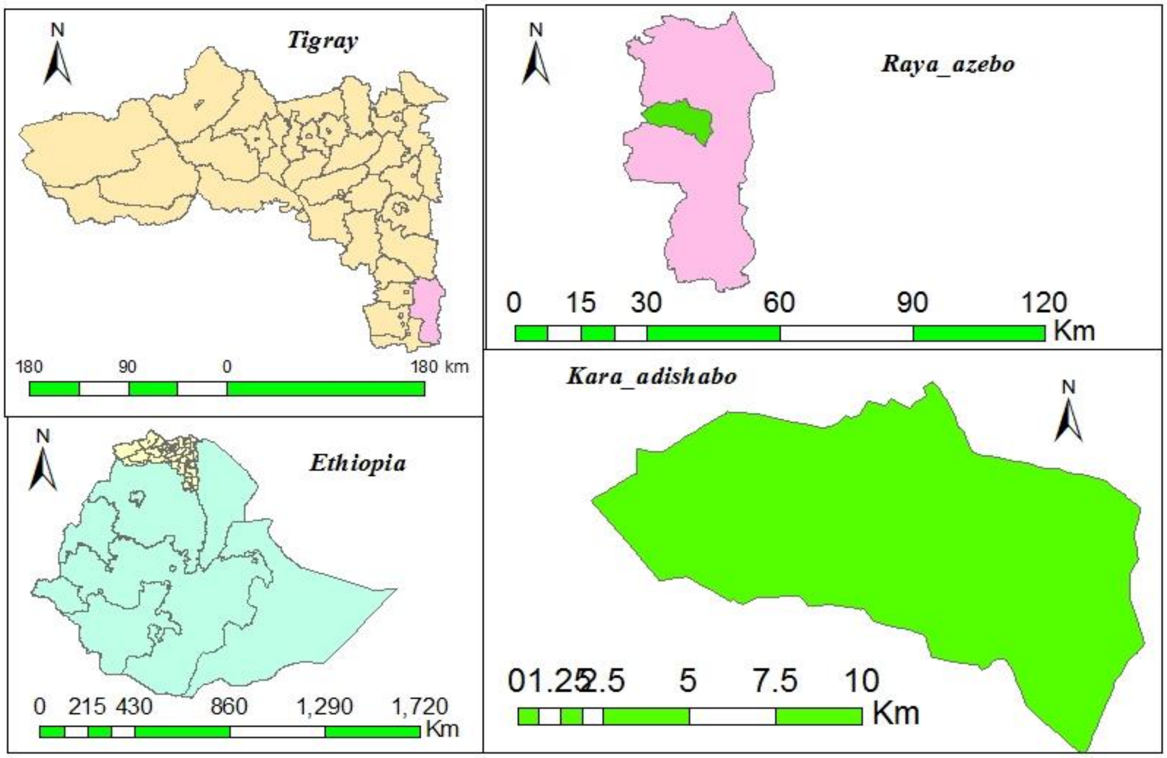

Figure 1. Location map of the study area

Table 1. Physical and chemical properties of different soil layers of Kara Adishabo site

Soil depth	Texture class	pH	EC (dsm^{-1})	SAR	CEC
0-15	Silt loam	8.6	0.30	1.02	60.99
15-30	Silt loam	8.5	0.26	1.16	59.72
30-60	Loam	8.6	0.40	0.97	77.06

Note: Adopted from Brhane (2016)

Table 2. Treatment levels of maize under deficit irrigation per growing stages

Treatment	Treatment name
T1	Farmers practices
T2	50 % deficit throughout all growing stages
T3	50% deficit at initial growth stage
T4	50% deficit at development growth stage
T5	50% deficit at mid growth stage
T6	50% deficit at late growth stage

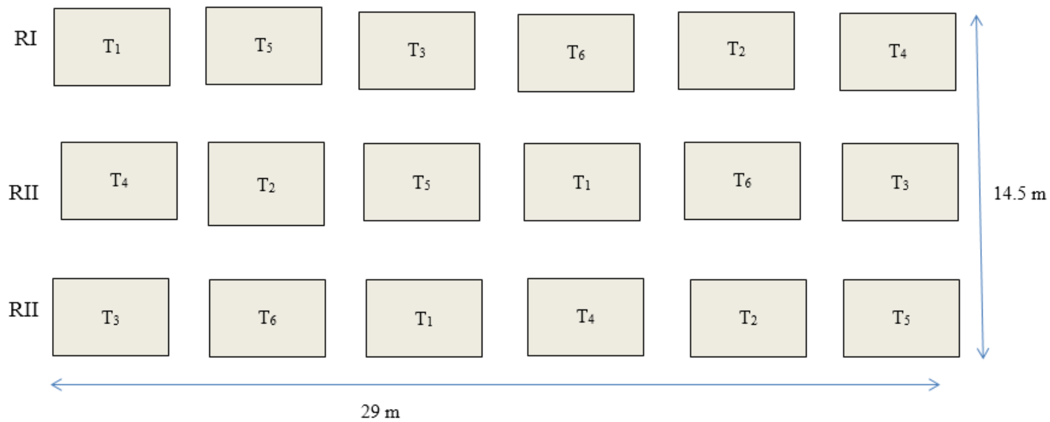

Figure 2: Layout of the experimental treatments

Enhancing yield and water productivity of maize at different deficit irrigation stages and levels starts from the calculation of crop water requirement and irrigation scheduling. The crop water requirements and irrigation scheduling were determined using CROPWAT 8.0 software (FAO 1992) for the four growing stages (initial, development, mid and late) of maize. The method of irrigation was furrow irrigated with an estimated application efficiency of 70%.

Data collection

The composite soil sample was collected from the experimental site and analysed at Mekelle soil research centre. The soil samples were taken from two depths (0-25 cm and 25-50 cm) and analysed separately. The major parameters analysed in the laboratory are EC, pH, organic matter, permanent wilting point, field capacity and bulk density. The total available water of the soil was computed from the results of field capacity and permanent wilting point. Relevant meteorological data was collected from nearby Maichew and Chercher stations.

The evapo-transpiration was calculated using Modified FAO Penman–Monteith method (Allen et al 1998). Since there was no effective rainfall during the study period, 100% of the crop water requirement was supplied by means of irrigation.

Statistical data analysis

Statistical analysis was done to yield and water use efficiency of maize using R statistical software (R Core Team 2016). The data of the experiment were analyzed in randomized complete block design (RCBD), and the mean difference was estimated using the least significant difference (LSD) comparison.

Results and Discussion

Irrigation water application

According to the result of CROPWAT 8 software the estimated maize crop water requirement was 642 mm. Irrigation water applications for each treatment were also determined based on the determined crop water requirement. Table 3 shows the levels of water application in different growing stages of the crop for the treatments.

Table 3. Summary of water application for the experimental treatments

Treatments	T1	T2	T3	T4	T5	T6
Water applied (m3/ha)	5559	4312	7641	7529	7289	7563

Maize yield components

The effect of the treatments on yield components (plant height and number of cobs per plant) did not show significant differences (at p = 0.05) in both cropping years, but the plant height parameter shows a significant difference in the combined analysis in which the 50% deficit at late growth stage shows a maximum height (2.06m) (Table 4).

Table 4. Effects of 50% irrigation deficit on yield components

Treatments	2017		2018		Mean	
	PH(m)	Cobs/plant	PH (m)	Cobs/plant	PH(m)	Cobs/plant
Farmers practice	2.102	1.67	1.675	1.667	1.889ab	1.417
50% deficit throughout all growth stages	1.854	1.67	1.751	1.133	1.804b	1.15
50% deficit at initial stage	2.14	1.333	1.741	1.467	1.94ab	1.4
50% deficit at development growth stage	1.838	1.25	1.761	1.333	1.799b	1.292
50% deficit at mid growth stage	2.07	1.25	1.775	1.267	1.924ab	1.258
50% deficit at late growth stage	2.145	1.417	1.979	1.267	2.063a	1.342
LSD	Ns	Ns	Ns	Ns	0.217	Ns
CV (%)	7.12	12.41	8.17	13.24	9.68	18.93

Grain and biomass yield

The experiment was conducted for two consecutive years and the maximum grain yield and biomass yield was obtained from 50% deficit at a late growth stage in both years (Table 5). The result of the treatments shows a significant difference in 2017 cropping season at (at P = 0.05). But in 2018 there was no statically significant difference among the treatments. The combined analysis of the two years shows a significant difference for both grain and biomass yield. The maximum grain yield was collected from stressing 50% at late season. Stressing all stages throughout the growing stage produces the lowest grain yield and this supports a study conducet by (Kifle and Gebretsadikan 2016).

Table 5. Effects of 50% irrigation deficit on grain and biomass yield in qt/ha

Treatments	2017		2018		Mean	
	Grain	Biomass	Grain	Biomass	Grain	Biomass
Farmers practice	31.52ab	156ab	19.5	71.55	25.51b	113.8b
50% deficit throughout all growth stages	24.25b	136.2b	22.43	92.98	23.34b	114.6b
50% deficit at initial stage	32.1ab	171.2ab	23.04	85.84	27.57ab	128.5ab
50% deficit at development growth stage	29.45ab	134.5b	21.65	87.03	25.55b	110.8b
50% deficit at mid growth stage	30.74ab	158.1ab	22.23	97.74	26.48ab	127.9ab
50% deficit at late growth stage	39.6a	193.1a	27.84	103.7	33.72a	148.4a
LSD	14.41	43.38	Ns	Ns	7.68	29.83
CV (%)	25.03	16.08	23.26	29.1	24.07	20.37

Note- 1 qt (quintal) = 100 Kg

Water use efficiency

Irrigation water use efficiency of the crop significantly affected by the use of different depth of water application (p = 0.05) for 2018 experiment and combined analysis (Table 6). There was no significant difference among the treatment in 2017. The minimum yield was harvested from 50% deficit irrigation through out the whole growing season and similar result were reported by (Aydinsakir 2013). The Irrigation water use efficiency was higher at 50% deficit throughout the whole growth stage and similar results were presented by (Ćosić et al 2015; El Mokh et al 2015; Igbadun et al 2012)

Table 6. Effects of 50% irrigation deficit on Irrigation water use efficiency

Treatments	2017 IWUE (Kg/m^3)	2018 IWUE (Kg/m^3)	Mean IWUE (Kg/m^3)
Farmers practice	0.5671	0.3508b	0.4604ab
50% deficit throughout all growth stages	0.5623	0.5203a	0.5418a
50% deficit at initial stage	0.4201	0.3016b	0.3608bc
50% deficit at development growth stage	0.3912	0.2876b	0.3388c
50% deficit at mid growth stage	0.4217	0.3049b	0.3641bc
50% deficit at late growth stage	0.5236	0.3681b	0.4457abc
LSD	Ns	0.133	0.111
CV (%)	23.7	21.08	24.19

Conclusion

The result of the study revealed that the grain yield, biomass yield and irrigation water use efficiency was affected by the level of irrigation water application. The highest grain (33.72qt/ha) and biomass yield (148.4qt/ha) was obtained from the 50% deficit irrigation at late growth stage of maize. The maximum irrigation water use efficiency was obtained from 50% deficit at all the four growth stages (0.5418 kg/ha) and at 50% deficit at late growth stage (0.446 kg/m3). Comparing the grain yield obtained at the 50% deficit at late growth stage (33.72qt/ha) and grain yield obtained at 50% deficit at all growth stages (23.34 qt/ha), the 50% deficit at late growth stage shows better results. The 50% deficit of crop water requirement did not affect the yield components (plant height & number of cobs per plant) of maize. Applying irrigation water by reducing the crop water requirement by 50% at the late growth stage has a significant contribution for sustainable and efficient irrigation water utilization at moisture deficient areas without a significant loss on grain and biomass yield.

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2.8. Response of Maize (*Zea mays* L.) to Deficit Irrigation on Yield and Water Use Efficiency at Selekleka, Ethiopia

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Abstract

Irrigation water availability is diminishing in many areas of the Ethiopian regions, which are requiring many irrigators to consider deficit-irrigation strategy. This study investigated the response of Maize (Zea mays L.) to moisture deficit under conventional, alternate and fixed furrow irrigation systems combined with three irrigation amounts over a two years period. The field experiment was conducted at Selekleka Agricultural research farm of Shire-Maitsebri Agricultural Research center. A randomized complete block design (RCBD) with three replications was used. Irrigation depth was monitored using a calibrated 2-inch throat Parshall flume. The effects of the treatments were evaluated in terms of grain yield, dry above ground biomass yield, other yield parameters and water use efficiency. The two years combined result indicated that total net irrigation water applied in Alternate furrow irrigation with full amount irrigation depth (100%ETc AFI) treatments was roughly half (3773.5m^3/ha) that of applied to the conventional furrow with full irrigation amount (CFI with100%ETc) treatments (7546.9m^3/ha). Despite the very significant reduction in irrigation water used with alternate furrow irrigation (AFI) there was a non-significant in Maize grain yield reduction (8.31%) as compared to control treatment (CFI with100%ETc). Significantly ($p<0.001$) higher crop water use efficiency of 1.889 kg m-3 was found in alternate furrow irrigation (AFI), than conventional furrow irrigation (0.988 kg m-3). Alternate furrow irrigation method (AFI) is taken as promising for conservation of water (3773.4m3/ha), time (23:22'50" hours/ha), labor (217.36USD/ha) and fuel (303.79USD/ha) for users diverting water from the source to their fields using pump without significant trade-off in yield.

Keywords: Grain yield, water use efficiency, water savings, deficit irrigation

Introduction

Ethiopia comprises 112 million hectares of (Mha) land. Cultivable land area estimates vary between 30-70 Mha. Currently, high estimates show that only 15 Mha of land is under cultivation. For existing cultivated area, the estimate is that only about 4-5 percent is irrigated; with existing equipped irrigation schemes covering about 640,000 hectares. These irrigation schemes vary widely in size and structure, from micro irrigation (rain water harvesting), to river diversion, pumping, and small or large dams (Awulachew et al 2010). Based on data from IWMI (in Awulachew et al 2010) and grey document from Ministry of water resource (MoWR) and ministry of agriculture and rural development (MoARD), from a total of 640,000 hectares of irrigation nationwide; 128,000 hectares from rain water harvest, 383,000 hectares from small scale irrigation (SSI), and 129,000 hectares from medium scale irrigation (MSI)/large scale irrigation (LSI).

In Ethiopia, irrigation development is increasingly implemented more than ever to supplement the rain-fed agriculture but due to the development of other water use sectors as well as increasing concerns for environment water has become increasingly a scarce resource. This water shortage has motivated some researchers and farmers to find ways to produce crop with less irrigation water and changing from fully-irrigated to deficit irrigated cropping system.

Deficit irrigation has been widely investigated as a valuable and sustainable production strategy in arid and semi-arid regions. It is one of the ways of maximizing water use efficiency (WUE) for higher yields per unit of irrigation water applied (Kirda 2002). Many studies have shown that there is a significant yield and yield component reduction occurs when maize produce under deficit irrigation.
Different works have been done on maize moisture deficit based on decreasing the amount of irrigation water. However, much work has not been done to determine the critical depth of water application where, the yield is not significantly affected. Therefore, considering the scarcity of irrigation water, this study was aimed to investigate the effect of irrigation levels and furrow methods on yield and water use efficiency for maize crop.

Methods and Materials

Description of the experimental area

This experiment was conducted at the Maitsebri Agricultural Research Center of Selekleka Agricultural Research site in 2017 and 2018. The site is located in Northern part of Tigray, Ethiopia at about 38.72°E longitude and 14.3°N latitude and at an altitude of 1782 meter above mean sea level. The long term mean monthly maximum and minimum temperature is 26.9°C and 11.2°C respectively. The average annual rainfall in the area is 678.32mm characterized by mono-modal type with rainy seasons from June to September. The soil of the area is characteristically well drained, light to dark brown in color and deep in depth, loamy sand in texture and continuously cultivated. The field capacity, permanent wilting point moisture content and available water holding capacity per unit meter of the soil profile in the root zone is 38.6%, 29.8% and 145.28mm respectively.

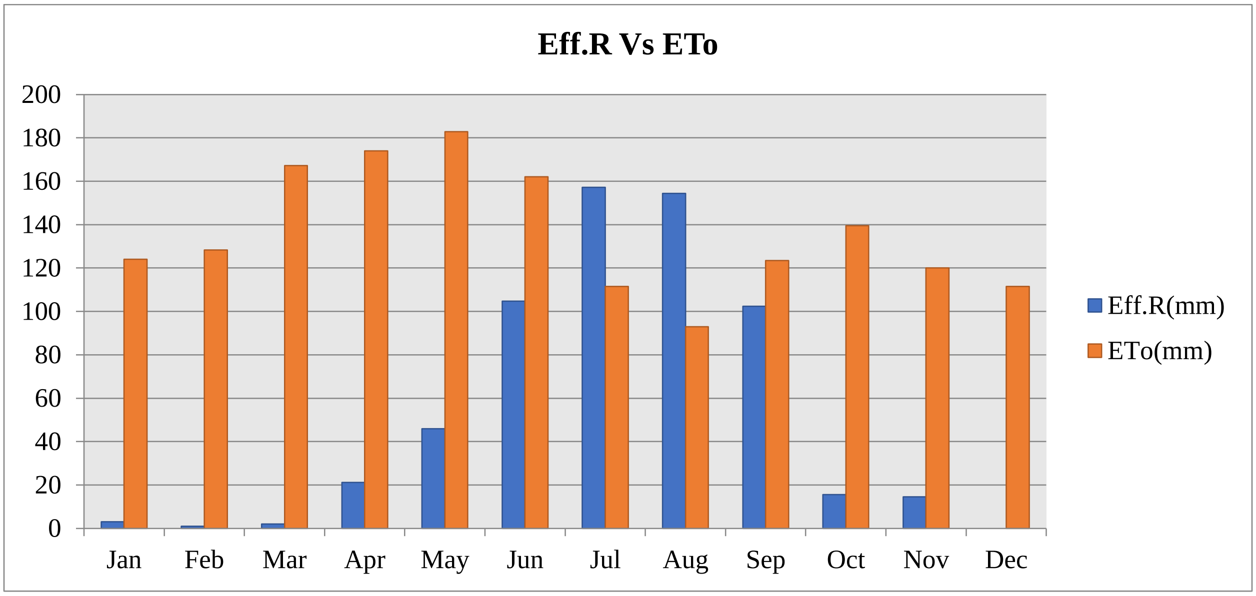

Figure -1: Monthly rainfall as compared with reference evapo-transpiration (ETo)

Treatments, experimental design and management

The experiment was designed as a two-factor factorial experiment in randomized complete block (RCBD) with three replications. The treatments were the combinations of three levels of furrow irrigation method (Alternate Furrow Irrigation, Fixed Furrow Irrigation and Conventional Furrow Irrigation) and three levels of irrigation applications (50%, 75% and 100% of ETc) (Table 1). Each experimental plot had an area of 8.4m^2, which consists of 4 furrows with 70cm width and 3m length. The recommended spacing of 30cm between plants was employed. The spacing between blocks and experimental plots was 2m and 1.5m respectively. Irrigation water was delivered to each plot using calibrated 2-inch Partial flume according to the treatments.

Maize (*Zea mays* L.) crop BH545 improved variety was used as test crop having growing period of 110-120 days in the study area. Maize variety BH-545 was planted on 15 December 2017 and 20 December 2018. Spacing between plants and raw was 30 and 70 cm respectively. Each experimental treatment was fertilized with equal recommended fertilizer application, that was 200kg/ha DAP and 150kg/ha UREA. The full doze of DAP was applied at the time of planting whereas UREA was applied by splitting in two parts, half during planting and the rest just at 30 days after weeding considering the size of the plots. There was no significant rain during both growing periods and full irrigation was applied. There were 14 irrigation events during the growing periods. All other agronomic practices were applied uniformly to all plots. Reference evapotranspiration, crop water requirements and irrigation schedule was determined using FAO Penman- Monteith method (Aallen 1998).

Table 1. treatment set up of the experiment

Treatment Code	Treatment Combination
T1	Alternate Furrow (AF) Irrigated at 100%ETc
T2	Alternate Furrow (AF) Irrigated at 75%ETc
T3	Alternate Furrow (AF) Irrigated at 50%ETc
T4	Fixed Furrow (FF) Irrigated at 100%ETc
T5	Fixed Furrow (FF) Irrigated at 75%ETc
T6	Fixed Furrow (FF) Irrigated at 50%ETc
T7	Conventional Furrow (CF) Irrigated at 100%ETc
T8	Conventional Furrow (CF) Irrigated at 75%ETc
T9	Conventional Furrow (CF) Irrigated at 50%ETc

AF meant each furrow alternately irrigated during consecutive irrigation events, FF meant that irrigation fixed to one of the two neighbouring furrows, CF meant irrigating all furrows. ETc represents for crop evapotranspiration

Data collection

Climatic data

Before the start of the experiment, secondary data such as climatic data of 20 years on rainfall (R.F.) min & max temperature, relative humidity (RH), wind speed (WS) and sunshine hours (SH) were collected from nearby meteorological station. Irrigation efficiency for furrow irrigation, root depth of tomato crop, tomato crop growing stages and their respective length of period and soil infiltration rate data was also collected from previous records and FAO guidelines.

Soil physical properties

Composite soil sample was collected from four depths (0-25 cm, 25-50cm, 50-75cm and 75-100cm). Parameters like texture, bulk density, field capacity, permanent wilting point and total available water in the soil was determined following the standard method. Soil physical properties of the study area are presented in (Table 2).

Table 2. soil physio-chemical properties of the study site

Soil properties	Sampling soil depth (cm)				
	0-25	25-50	50-75	75-100	Average
Particle Size Distribution					
- Sand (%)	60	56	54	56	56.5
- Clay (%)	16	18	18	18	17.5
-Silt (%)	24	26	28	26	26
-Textural Class	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
Bulk density (g/cm^3)	1.38	1.34	1.33	1.31	1.34
Field Capacity (weight basis %)	30.3	37.8	38.9	38.6	36.4
Permanent Wilting (weight basis %)	24.8	22.2	25.3	29.8	25.53
Total Available Water (mm/m)					145.28

Grain yield and yield components

Grain yield, above ground dry biomass yield data was collected from the central quadrant plot size of $4.2m^2$ and extrapolated to hectare basis. Plant height and cob length were collected from six plant samples randomly selected from the two central furrows and averaged to get the average value in plant height and cob length. Days to 50%female silking and 50% male anthesis, was observed when 50% of the plants emerge silk and anthesis respectively.

Data analysis

Analysis of variance was performed following the procedures of Gomeze and Gomez (1984) using Gen Stat statistical software. Treatments showing significant difference were subjected to Duncan's multiple range test (DMRT) for mean separation at 95% of confidence level.

Results and Discussion

Water consumption and irrigation demand

Precipitation during the months December to May in both years was insignificant. As a result, throughout the growing period of the test crop, the only source of water was irrigation. Totally, 14 irrigation events were adopted during the crop growing period. The total amount of net applied irrigation water according the treatments are presented below in Table-3. The optimum seasonal irrigation requirement in the area for maize was found to be 754.69 mm ($7546.9m^3$/ha) for every furrow irrigation method (Table-3). Similarly, for the alternate furrow irrigation (AFI) and fixed furrow irrigation (FFI), 377.35mm (3773.5m^3/ha) of water was needed throughout the growing season at full crop evapotranspiration(100%ETc) (Table-3). As we observed from Table-3 above, the alternate furrow and fixed furrow irrigation treatments at optimum crop water requirement (100%ETc) consumed less water as compared with every furrow irrigation method

Table-3. Total Seasonal Net Irrigation Depth Applied to Treatments

S.No	Treatments	Net irrigation depth (mm)
1	CFI100%ETc	754.69
2	AFI/FFI 75%ETc	283.11
3	CFI 50%ETC,AFI/FFI 100%ETc	377.35
4	CFI75%ETc	566.23
5	AFI/FFI 50%ETc	188.83

AFI, Alternate furrow irrigation, FFI, fixed furrow irrigation, CFI, Conventional furrow irrigation and ETc, Crop evapotranspiration

The total seasonal amount of water consumed by the alternate furrow irrigation and conventional furrow irrigation under full crop water requirement (100%ETc) were amounted to be 377.35mm (3773.5m^3/ha) and 754.69 mm (7546.9m^3/ha) respectively. According to the FAO guidelines the approximate value of seasonal crop water requirement of Maize for maximum yields is 500 to 800 mm depending on climate (Willy et al 1991). The amount of water applied for conventional furrow irrigation treatment was agreed with the range of water requirement stated above. Amount of water applied under alternate furrow irrigation was also agrees with conclusion says alternate furrow irrigation is commonly applied as part of a deficit irrigation program because it does not require the application of more than 50–70% of the water used in a conventional furrow irrigation method (Webber et al 2006). On the other hand, alternate furrow irrigation technique recorded lower values of total evapotranspiration as compared with conventional furrow irrigation technique. This is due to the half irrigation of the planting area, and the fact that the root absorbed water only from some parts of the soil (Barideh and Besharat 2018). Table -3 indicates that alternate furrow and fixed furrow irrigation techniques saved 50% of irrigation water as compared with conventional furrow irrigation at full irrigation requirement (100%ETc).
The lowest depth of water applied under alternate furrow irrigation method as compared to conventional furrow irrigation is as a result of great reduction of wetted surface. This result supports the outcome obtained by the study that conclude alternate furrow irrigation method

which can supply water in a way greatly reduces the amount of wetted surface, which leads to less evapotranspiration and less deep percolation (Shayanneja and Moharreri 2009)

Yield and growth parameters

Plant height and cob length

The two years over year statistical analysis showed that, plant height and cob length of maize had not affected by application of different irrigation levels ($P<0.05$). However, as the deficit irrigation level increases the plant height decreases as indicated from Table-5. Similar research findings as in the case of (Rosadi et al 2005) discovered that a small difference in moisture deficit levels did not affect plant height. Our research findings is also in agreement with a research finding done on Bulga-70 common Bean cultivar said that plant height is not statistically different for 100, 75 and 50% of crop evapotranspiration (Abiot 2018). In this experiment, we had not observed combined influence of irrigation levels and furrow methods on plant height of maize crop (Table-4).

However, application of different furrow irrigation methods significantly influenced pant height and cob length of maize production. The highest in plant height (1.76 m) and cob length (18.30 cm) was produced under conventional furrow irrigation method, where as the lowest in plant height (1.48 m) and cob length (15.54 cm) was obtained from fixed furrow irrigation method (Table-5). As seen from Table-4, combined effect of irrigation levels and furrow methods had observed very highly significant ($P< 0.001$) on cob length of maize.

Grain yield and above ground dry biomass yield

The two years combined analysis of Maize (*Zea mays* L.) indicates a very highly significance influence ($p<0.001$) due to the adoption of both different furrow irrigation methods as well as irrigation levels on grain and above ground dry biomass yield (Table-4). The interaction effect of irrigation deficit levels and furrow methods is also very highly significant ($p<0.001$) on maize grain yield and significant ($p<0.05$) on above ground dry biomass yield. The result revealed that, conventional furrow irrigation with 100% crop evapotranspiration(ETc) gave the highest grain yield (7323.3kg/ha) and dry biomass yield(19.69 tons/ha) followed by alternate furrow irrigation with 100% cropevapotranspiration(ETc) to be 6714.8 kg/ha and 14.18 tons/ha respectively(Table-5).The minimum in grain yield (2647.5 kg/ha) and dry biomass yield (9.31tons/ha) was obtained from fixed furrow irrigation at 50% of cropevapotranspiration(ETc) (Table-5).The major finding here is that, irrigation water applied to alternate furrow irrigation method with 100%ETc is 50% less than that of applied to Conventional furrow irrigation with 100%ETc and the yield reduction was 8.31%.

This implies that, applying alternate furrow irrigation will not produce significant yield reduction as compared with conventional furrow irrigation method in terms of grain yield. While the above ground biomass yield decreased significantly in alternate furrow irrigation compared to conventional furrow irrigation (Table-5). The highest (19.69 tons/ha)and the lowest (14.18 tons/ha) in dray above ground biomass yield was obtained from conventional and alternative furrow irrigation methods with 100%ETc respectively. Many researchers conducted research on deficit irrigation on different crop types such as (Jonghan and Giovanni 2009); (Simsek et al 2011) revealed that, as the moisture deficit level increased the production of the crop will declined, which agreed with the current finding. Other reports conducted by (Robel et al 2019) on soybean, (Meskelu et al 2018) and (Mohammed and Kannan 2015) on maize crop discovered that above ground dry biomass yield is higher for conventional furrow irrigation system than alternate and fixed furrow irrigation methods which supports our current findings.

Water use efficiency (WUE)

there was significant difference at 0.1% and 1%significant levels in water use efficiency (WUE) values between different furrow systems as well as different deficit levels of irrigation. The highest water use efficiency value was 1.889 kg/m^3 and 1.584 kg/m^3 obtained from the alternate furrow irrigation and 50%ETc treatments respectively whereas, the lowest value of 0.988 kg/m^3 and 1.188 kg/m^3 was obtained from conventional furrow irrigation and 100%ETc treatments respectively (Table-5).Therefore, the above data analysis showed application of 50 %ETc and alternative furrow (AF) perform well in accordance with water use efficiency of Maize with saving of more water and no significant yield reduction .It will save 50 % water applied as compared to application of conventional furrow system and application of 100 % ETc. This finding agreed with result states that, applied water was used more efficiently in the alternate furrow irrigation treatment in which the lower amount of water applied produces higher water use efficiency value (Addisu Tadesse & Seyoum T 2018).

Table-4: Analysis of variance on important Agronomic parameters of Maize

Source of Variation	Plant Height	Cob length	Grain yield	AGBY	WUE
Irrigation Levels	ns	ns	***	***	**
Furrow Methods	**	**	***	***	***
Irrigation *Furrow	ns	***	***	*	*

, **, ** and **ns** indicate significant at (P<0.05), (P<0.01) and (P<0.001) ns – non significant respectively, ABGY, above ground dry biomass yield, WUE, Water use efficiency

Table-5: Statistical comparison of the mean values of relevant Parameters of Maize

Source of variation	PH (m)	CL (cm)	Gyld (Kg/ha)	AGBY (t/ha)	WUE (kg/m^3)
Irrigation levels(%ETc)					
100%ETc	1.66^{a}	16.59^{a}	5704.8^{a}	15.05^{a}	1.188^{b}
75%ETc	1.64^{a}	16.12^{a}	4583.9^{b}	11.06^{b}	1.311^{b}
50%ETc	1.62^{a}	16.01^{a}	3663.2^{c}	10.86^{b}	1.584^{a}
P-Value	0.232	0.085	<0.001	<0.001	0.005
Furrow Irrigation Methods					
Conventional	1.76^{a}	18.30^{a}	5531.5^{a}	15.28^{a}	0.988^{b}
Alternate	1.612^{c}	16.12^{b}	5190.3^{a}	11.81^{b}	1.889^{a}
Fixed	1.480^{b}	15.54^{b}	3229.7^{b}	9.89^{c}	1.206^{b}
P-Value	<0.001	<0.001	<0.001	<0.001	<0.001
Furrow Methods *Irrigation levels(%ETc)					
Alternate furrow and 100%ETc	1.469^{a}	14.43^{cd}	6714.8^{a}	14.18^{b}	1.778^{b}
Conventional furrow and 100%ETc	1.795^{a}	20.83^{a}	7323.3^{a}	19.69^{a}	0.972^{cd}
Fixed furrow and 100%ETc	1.720^{a}	16.70^{bc}	3075.2^{ef}	11.29^{cde}	0.815^{d}
Alternate furrow and 75%ETc	1.572^{a}	16.77^{bc}	4548.6^{bcd}	10.63^{de}	1.607^{b}
Conventional furrow and 75%ETc	1.695^{a}	17.57^{b}	5238.2^{bc}	13.48^{bc}	0.925^{d}
Fixed furrow and 75%ETc	1.619^{a}	17.77^{b}	3964.5^{de}	9.07^{e}	1.400^{bc}
Alternate furrow and 50%ETc	1.405^{a}	14.43^{d}	4310.8^{bcde}	10.62^{de}	2.288^{a}
Conventional furrow and 50%ETc	1.790^{a}	16.50^{bc}	4032.3^{cde}	12.65^{bcd}	1.068^{cd}
Fixed furrow and 50%ETc	1.491^{a}	13.90^{d}	2647.5^{f}	9.31^{e}	1.402^{bc}
Mean	1.62	16.65	4650.3	12.33	1.361
C.V (%)	10.7	9.6	20.5	16.0	25.7
P-Value	0.203	<0.001	<0.001	0.035	0.031

PH: Plant height, CL: Cob length, Gyld: Grain yield, AGBY: Above ground dry Biomass yield, WUE: Water Use Efficiency, ETc, Crop evapotranspiration

The higher mean value of water use efficiency obtained under alternate furrow irrigation was related to lower amount of water applied with uniform lateral movement in crop root zone and minor grain yield reduction obtained under this method. The reason for better water use efficiency (WUE) and minor yield reduction for alternate furrow irrigation could be related to improve lateral distribution of water in root zone that increases water and fertilizer uptakes by plant. This result indicates that alternate furrow irrigation is appropriate to increase water use efficiency by allowing to apply less irrigation water for maize production which supports the outcome of the study that says using alternate furrow irrigation can be produced higher water use efficiency (WUE) (Saeed et al 2008)

Additional area gained

Table-6 indicated that amount of water saved under alternate and fixed furrow irrigation methods comparing with conventional furrow. This table also indicated that additional area can be irrigated by amount of water saved under alternate and fixed furrow irrigation methods. Alternate furrow irrigation and fixed furrow irrigation saved 377.34mm (3773.4m^3/ha) of water applied under conventional furrow irrigation method which can be used to irrigate 1ha of additional land using alternate furrow or fixed furrow irrigation method for maize production. Moreover, applying alternate furrow irrigation method improved water use efficiency and saved 3773.4m^3/ha (50%) of water consumed under conventional furrow irrigation method. Alternate furrow and fixed furrow irrigation received the same amount of irrigation water, whereas low water use efficiency was obtained under fixed furrow irrigation compared to alternate furrow irrigation method. This result is in close agreement with the conclusion that alternate furrow irrigation increase water use efficiency as compared with fixed furrow irrigation techniques by saving irrigation water (Jovanovic et al 2010).

Generally, the alternate furrow irrigation system increased water use efficiency (WUE) with minor or no yield reduction as compared to conventional furrow irrigation method. The finding of this study agrees with result of the studies that conclude alternate furrow irrigation increases water productivity with minor or no yield reduction and save substantial quantity of irrigation water (Nasab and Nouri 2011).

Table-6: Irrigation water saved and additional area gained under furrow irrigation treatments

Treatments	Irrigation water Consumed(m^3/ha)	Irrigation water saved (m^3/ha) Comparing with CFI	Additional area can be irrigated (ha)
AFI	3773.5	3773.4	`1
FFI	3773.5	3773.4	1
CFI	7546.9	0	0

AFI, FFI and CFI, Alternate furrow irrigation, fixed furrow irrigation and CFI, Conventional furrow irrigation

Conclusion and Recommendation

Results confirmed that irrigation treatments significantly influenced yield, water use efficiency and other most parameters. The grain yield reduction observed under alternate furrow irrigation is less than 6.16 % as compared with conventional furrow irrigation method, which has no significant difference. The highest grain yield (5531.31 hg/ha) was obtained from conventional furrow irrigation followed by 5190.3 kg/ha from alternate furrow irrigation. Alternate furrow and fixed furrow irrigation methods saved 50% of water applied compared to conventional furrow irrigation method. However; under fixed furrow irrigation method low water productivity was recorded as compared with alternate furrow irrigation method. This study promotes that alternate furrow irrigation was considerably saved water than conventional furrow irrigation method without significant yield reduction.

Therefore, applying alternate-furrow irrigation with appropriate irrigation intervals is efficient method in the study area where soil is mainly dominated by sandy loam and when water becomes limiting factor in maize production. The predilection between alternate furrow irrigation method and other methods depends on the value of water and crop returns. This water application technique is much important in the study area in particular, in Ethiopia in general where limited amount of water is available for irrigation and irrigation water management is very traditional.

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2.9. Growth Stage Based Water Stress on Yield and Water Use Efficiency of Tomato (*Solanumlycopersicon*L.)

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Abstract

This study was aimed to determine the sensitive growth stage and to optimize tomato production under deficit irrigation Strategy. A two-year field experiment was carried out at Maitebri Agricultural Research Center; Selekleka experimental site during 2017 and 2018 off seasons. The experimental design was randomized complete block design (RCBD) with three replications. Three irrigation levels (100%, 50%, and 25% crop evapotranspiration) and FAO based four growth stages of tomato was considered. Irrigation water being applied, Marketable yield, yield components (number of fruits per plant, Fruit length, Fruit circumference) and crop water use efficiency (WUE) were recorded. Results showed that, reducing the full crop water requirement amount up to 75% at development growth stage can severely reduce the marketable yield up to 66.5%. On the other hand, the highest in water use efficiency (9.2kgm^{-3}) was obtained with reducing the full crop water requirement by 75% at the end growth stage of tomato. The lowest in water use efficiency (3.5kgm^{-3}) was obtained from treatments that were irrigating 75% below the full crop-evapotranspiration at development growth stage. Generally, reducing irrigation water below 75%ETc during development growth stage of tomato can significantly influence the marketable, water use efficiency and growth parameters. Therefore, tomato crop is very sensitive to water stress beyond 50% of the full crop evapotranspiration (ETc) at its developmental growth stage.

Key words: Water stress; water use efficiency; Marketable yield; Crop growth stages

Introduction

Deficit irrigation is one of the best irrigation water saving techniques. The goal of deficit irrigation is to increase crop water use efficiency (WUE) by reducing the amount of water that is applied or by reducing the number of irrigation events (Kirda 2002). The deficit irrigation technique irrigates the root zone with less water than that is required for evapotranspiration and makes use of suitable irrigation schedules, which are usually derived from field trials (Oweis and Hachum 2001). Crop tolerance to deficit irrigation during the growing season changes with the phonological stage (Istanbulluoglu 2009). Optimal irrigation schedules are often based on water productivity (Oweis and Hachum 1998). Deficit irrigation strategies have the potential to optimize horticultural water productivity. Nevertheless, the effects of deficit irrigation on yield or harvest quality are crop specific (Costa and Ortuno 2007). Information on how different crops cope with mild water deficits forms the basis for a successful application of deficit irrigation.

Tomato (*Solanum lycopersicon* L.) is one of the most important vegetable crop and is one of the most demanding in terms of water use (Peet 2005). The application of deficit irrigation (DI) strategies to this crop may significantly lead to save irrigation water (Costa and Ortuno 2007). Furthermore, studies have shown that water deficit occurs during certain stages of the growing season to improves fruit quality, although water limitations may determine fruit yield losses (Patane and Cosentino 2010). Adoption of deficit irrigation (DI) strategies in which 50% reduction in crop evapotranspiration (ETc) was applied for the whole or partial growing season to save water helped to minimize fruit losses and maintain high fruit quality (Patane and Sortino 2011). Pulupol et al (1996) observed a significant reduction in dry mass yield for a glasshouse tomato cultivar using deficit irrigation, while Zegbe-Domínguez et al (2006) did not find a reduction in tomato fruits yield of field-grown processing cultivar. Although, the effects of deficit irrigation (DI) on tomato fruits yield may be different, many investigators have demonstrated that deficit irrigation saves substantial amounts of irrigation water and increases water use efficiency (WUE). Hence this study was aimed to determine the sensitive growth stage and to optimize tomato production under deficit irrigation.

Methods and Materials

Experimental location, design, treatments and management

The experiment was conducted in Selekleka research farm of Shire-. Maitsebri Agricultural Research Center. The research site is located at 38.72°E and 14.3°N and at an altitude of 1782m above mean sea level. The long term mean monthly maximum and minimum temperature is 26.9°C and 11.2°C respectively. The average annual rainfall in the area is 678.32mm with uni-modal type with rainy seasons from June to September. The most dominant soil texture of the experimental site is Loamy sand. The source of irrigation water for the experiments was from hand dug wells with average seasonal EC of 3.2 dS/m. Tomato seedlings were transplanted at 25days from nursery to the experimental field with equal size.

The total growing period of Tomato crop in the study site is 110 days from the date transplanting. Four growth stages were considered (initial 23 days, development 30 days, mid 34 days and late 23 days). There were nine treatments (Table 1) derived from three levels of irrigation depths (100, 50 and 25% ETc) and four levels growing stages (initial, development, mid and late).

Table 1. Treatment setup of the experiment

Growing stages	Treatments (amount of water applied per each stages in % of ETc)								
	T1	T2	T3	T4	T5	T6	T7	T8	T9
Initial	100	50	100	100	100	25	100	100	100
Development	100	100	50	100	100	100	25	100	100
Mid	100	100	100	50	100	100	100	25	100
Late	100	100	100	100	50	100	100	100	25

N.B: 100, 50 and 25 means application of 100%, 50% and 25% of ETc respectively

The experiment was laid out in randomized complete block design (RCBD) with three replications. Each experimental plot had an area of 9.6m^2, which consists of 5 furrows with 64cm width and 3m length. The recommended spacing of 30cm between plants was used. Irrigation water was applied to each plot using calibrated 2-inch Partial flume according to the treatments. Each experimental treatment was fertilized equally with recommended rate of 200kg/ha DAP and 100kg/ha UREA. DAP was fully applied at the time of transplanting and UREA was applied by splitting in two parts, one-third at time of transplanting and the rest just at 30 days after transplanting. All other agronomic management was applied uniformly to all plots as per the standard recommendations of the crop.

Data collection

Climatic data

The secondary data collected during this research include climatic data of 20 years on rainfall (R.F.) minimum and maximum temperature, relative humidity (RH), wind speed (WS) and sunshine hours (SH). Irrigation efficiency for furrow irrigation, root depth of tomato crop, tomato crop growing stages and their respective length of period and soil infiltration rate data was also collected.

Soil physical properties

Three soil profiles were randomly made in the experimental site to measure soil properties. Soil texture was determined using the pipette method (Gee and Bauder 1986) at 0-25 cm, 25-50cm, 50-75cm and 75-100cm depths for each of the three soil profiles. Bulk density was determined by core method (Blake and Hartage 1986) for each depth in the three profiles. Soil water content was determined for disturbed samples from the same pervious locations using gravimetric method. Field capacity and permanent wilting points were considered at 0.3 and 15.0 bars, respectively (Klute 1986). The soil basic infiltration rate was determined in the field using double ring infiltrometer method in two separate sites in the experimental area as described by (Bouwer 1986) (Table 2).

Tabl-2. Average physical soil properties of the experiment site

Soil depth(cm)	Texture	FC (%)	PWP (%)	BD (gm/cm^3)	TAW (mm)	IR (mm/hr)
0-25	SL	0.303	0.248	1.38	18.975	65.23
25-50	SL	0.378	0.222	1.34	52.26	
50-75	SL	0.389	0.253	1.33	45.22	
75-100	SL	0.386	0.298	1.31	28.82	

SL= Sandy Loam, FC= field capacity moisture content, PWP= permanent wilting point moisture content, BD= Soil Bulk density, TAW= Total available moisture content and IR= Infiltration rate

Fruit yield and yield component

Yield data were collected from three central furrows of tomato planted plots. Plant height, number of fruits per plant and cluster number were collected from five plant sample of the three central rows.

Data analysis

Analysis of variance was performed following the procedures of (Gomez 1984) using Gen Stat statistical software. Treatments showing significant difference were subjected to Duncan's multiple range test (DMRT) for mean separation at 95% of confidence level**.**

Result and Discussion

The two years combined analysis of variance revealed that there is a highly significant ($P<0.01$) difference among treatments due to moisture deficit at different growth stages in most of the agronomic parameters. Marketable and non-marketable yield, Fruit length, Fruit circumference and water use efficiency (WUE) significantly respond to deficit irrigation at different growth stages of the crop (Table-3). As presented in (Table 4) irrigating 25% ETc at Maturity stage with full amount at other stages gave the highest over year mean marketable yield (427.3Q/ha).The minimum in marketable yield (144Q/ha), Fruit length (3.48cm) and fruit circumference (6.42cm) was obtained from plots that was irrigating 25%ETc at development stage and full amount at other stages. The lowest in water use efficiency, WUE (3.475kg/m^3) was obtained from plots that were irrigating 25%ETc at development stage and full amount at other stages. The result revealed that stressing Tomato beyond 50% ETc at development growth stage, extremely influenced marketable yield and yield parameters.

The magnitude of yield response factor (Ky) value indicates the sensitivity of the irrigation protocol for water stress and subsequent yield decrease. Form the result shown in Table- 5; the highest Ky value was 3.72, attained at the treatment of irrigating 25%ETc at development stage with full amount at other stages. The higher Ky values could be an indication of severity water stresses at that stage on Tomato marketable yield. The lowest in yield response factor (0.14) was observed at treatments that were irrigating 50%ETc at mid growth stage with full amount at other stages indicating that the water deficit at this stage did not affect Tomato marketable yield significantly.

Table-3. Combined ANOVA result on Agronomic Parameters of Tomato (2017-2018)

Source of Variation	50% DFl	50% DFS	FNPP	FL(cm)	FCir(cm)	Myld (Q/ha)	UnMyld (Q/ha)	WUE (kg/m^3)
Treatments	NS	NS	NS	***	***	*	***	***

*, ** and *** indicate significance at the 5% and 1% and <0.1% levels respectively ,NS= Not Significance, DFl, Days to flowering, DFS, Days to fruit setting, FL, Fruit length, FCir, Fruit circumference ,FNPP, fruit number per plant , Myld, Marketable yield, UnMyld, Unmarketable yield, WUE, Water use Efficiency

Table-4: Treatment effects on yield parameters and WUE of Tomato (2017-2018 Combined)

Trts	50% DFl	50% DFS	FNPP	FL (cm)	FCir (cm)	Myld (Q/ha)	UnMyld (Q/ha)	WUE (kg/m^3)
T1	57.83^a	67.83^a	14.21^a	7.47^a	12.12^a	431.9^a	44.10^a	6.9^a
T2	54.83^a	67.17^a	15.42^a	5.61^{bcd}	10.59^{ab}	413.9^a	17.31^a	7.6^a
T3	57.17^a	68.00^a	14.10^a	4.65^d	8.48^c	394.1^a	16.53^a	7.8^a
T4	57.17^a	67.50^a	16.93^a	6.75^{ab}	11.53^a	419.1^a	18.0^a	9.01^a
T5	57.50^a	69.17^a	15.94^a	5.86^{bcd}	11.27^a	386.4^a	18.53^a	7.7^a
T6	59.17^a	65.60^a	14.01^a	6.07^{bc}	10.77^{ab}	386.1^a	14.48^a	7.3^a
T7	55.00^a	68.17^a	12.86^a	3.48^e	6.42^d	144.3^b	101.88^b	3.5^b
T8	56.17^a	67.33^a	13.82^a	5.09^{cd}	9.04^{bc}	365.2^a	17.92^a	9.1^a
T9	54.83^a	68.00^a	16.86^a	5.88^{bcd}	11.79^a	427.3^a	25.52^a	9.2^a
Mean	56.63	67.85	14.91	5.65	10.22	382.7	21.0	7.56
LSD	ns	ns	ns	1.136	1.756	142	32.11	3.82
C.V (%)	6.3	4.6	39.2	17.1	14.6	32.7	30.50	30

Columns assigned with the same letter have not significant difference. Trts, Treatments, DFl, Days to flowering, DFS, Days to fruit setting, FL, Fruit length, FCir, Fruit circumference, FNPP, Fruit yield per plant, Myld, Marketable yield, UnMyld, Unmarketable yield, WUE, Water use Efficiency

Table 5. Tomato yield response factor (Ky) to moisture stress condition

Trts	$Yac/Ymax$	$ETac/ETmax$	$\left(1-\frac{Yac}{Ymax}\right)$	$\left(1-\frac{ETac}{ETmax}\right)$	Ky
T1	1.00	1.00	0.00	0.00	-
T2	0.95	0.94	0.05	0.06	0.83
T3	0.91	0.88	0.09	0.12	0.75
T4	0.97	0.79	0.03	0.21	0.14
T5	0.89	0.87	0.11	0.13	0.85
T6	0.89	0.92	0.11	0.08	1.38
T7	0.33	0.82	0.67	0.18	3.72
T8	0.84	0.68	0.16	0.32	0.5
T9	0.92	0.81	0.08	0.19	0.4

Y_{ac}, Actual yield, Y_{max}, Maximum Yield, ET_{ac}, Actual crop Evapotranspiration, ET_{max}, Maximum crop Evapotranspiration, K_y , Yield response factor, ETc, Crop Evapotranspiration and Trts, Treatments

Conclusion

The study revealed that, the maximum marketable yield (431.9Q/ha) was obtained from full irrigation amount at all growth stages. However, the marketable yield difference did not statistically significance as compared to other treatments except with application of 25% ETC at development stage. The maximum water productivity (9.2kg/m^3) was obtained from treatments that were irrigating 25%ETc at late stage and full amount at other stages. Stressing the tomato plant beyond 50% ETc at development stage resulted in 67% yield loss.

Therefore, it can be concluded that imposing moisture stress up to 75% ETc at initial, mid and late season stages with full amount at other stages was not significantly reduced the tomato marketable yields and water use efficiency. However, moisture stress up to 75% ETc at development stage exhibited low water use efficiency and marketable yield. Moreover, more stressing moisture up to 75%ETc at development crop growth stage is no advisable. Therefore, in area where irrigation water is scarce one can use stressing irrigation water up to 75% at initial, mid and late growth stage to save a considerable amount of water with 10.4%, 15.4% and 1% respectively. But if the water resource is not scarce, application of full crop water requirement is recommended.

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2.10. Homegarden Agroforestry as a Multi-Functional Land-Use Strategy with Focus on Carbon Stocks and Woody Species Conservation: The Case of Southern Zone of Tigray, Ethiopia

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Abstract

This study aims to estimate and compare the woody species diversity, carbon stocks and to analyze the relationship between woody species diversity and carbon stocks of home garden agroforestry system (HGAFs) along altitudinal gradients. Purposefully three altitudinal gradients were selected based on the presence of HGAFs. A total of 33 plots with a size of 10mx20m was used to collect vegetation data. For biomass carbon stock and soil samples randomly 30 sample plots were taken. The total number of soil samples was 120 i.e. 60 composites for soil carbon and 60 undisturbed for bulk density analysis from 0-30cm and 30-60cm soil depths. Biomass estimation of each woody species was analyzed by using appropriate species-specific and general allometric equations. Woody species richness was significantly higher in HGAFs of lower and higher altitudes than in middle ($p<0.05$). However, species diversity and evenness were not varied significantly among altitudinal gradients. The total amount of carbon stocks was 147.82 ± 31.76; 138.24 ±28.55 and 104.99 ± 27.42 tons ha^{-1} in the middle, lower and higher altitudes respectively and it was significantly higher in lower altitudinal gradient ($p < 0.05$). Positive but not significant ($p>0.05$) relationship between carbon stocks and woody species diversity and richness were found. Density in all altitudes was positively and significantly correlated with biomass carbon. Generally, the results show that variation in altitudinal gradients is one of the major determinant factors for woody species richness and carbon stocks on HGAFs. Therefore, HGAFs in the lower and middle elevations which support livelihoods and provide food are essential for the conservation of woody species and ensure climate change mitigation.

Keywords: Climate change, Mitigation, Northern Ethiopia, soil organic carbon

Introduction

Homgarden agroforestry system (HGAFs) is defined as land-use practices involving deliberate management of multipurpose trees and shrubs in intimate association with annual and perennial agricultural crops and invariably, livestock, within the compounds of individual houses, the whole crop-tree-animal unit being managed by the family labor (Fernandes & Nair 1986). These are distinct from other forms of agriculture in their ability to store higher amounts of carbon (C) in the above- and belowground biomass, soils, and products (Montagnini and Nair 2004) and directly increase biodiversity while reducing habitat loss and fragmentation (Schroth et al 2002). The tropical range of biomass C storage potential of agroforestry systems is estimated to 12-228 tons C ha^{-1} (Albrecht and Kandji 2003). Montagnini and Nair (2004) give an estimate of the C sequestration of mainly tropical agroforestry systems of 1.5–3.5 tons C ha^{-1} y^{-1}.

Carbon sequestration is an important part of an overall carbon management strategy in the reduction and mitigation of global CO_2 emission. Biomass is a key property of ecosystems (Chapin et al 2002; Fahey and Knapp 2007) that results from the mass balance between rates of gain due to productivity and losses due to respiration and mortality (Keeling and Phillips 2007). Live aboveground biomass stocks vary widely among HGAFs due to differences in stem size distribution, soil fertility and topography as well as management of the farmer (Castilho et al 2006; Murthy et al 2016; Salunkhe et al 2016).

Different environmental factors change systemically with altitude. Depending on altitudinal gradients and regional climate the rate of change in vegetation structure with altitude varies greatly (Bruijnzeel 2002; Bruijnzeel and Veneklaas, 1998). The differences in woody species structure and biomass stocks in HGAFs may be found among sites over short distances. The general trends for high altitudinal gradients are a decline in woody species stature and live aboveground biomass while stem density increases with altitude (Kitayma and Aiba 2002); (Moser et al 2007; Tanner et al 1998). This pattern has been explained as a result of climatic constraints on photosynthesis and transpiration and nutrient uptake with increasing altitude (Bruijnzeel and Veneklaas 1998; Kitayma and Aiba 2002); Raich et al 2006).

Therefore, altitudinal gradients are among the most governing natural experiments for testing ecological and evolutionary responses of biota to environmental changes. Information on HGAFs woody species diversity and carbon stock and its allocation along the altitudinal gradients will help to better predict the responses of regional and global C balance to future climate change and to conserve biodiversity. So understanding the role of environmental variables that control the distribution and abundance of woody species diversity and biomass conservation in HGAFs at different altitudinal gradient is crucial. Even though, the altitudinal pattern of woody species carbon stocks and conservation of biodiversity in forest ecosystems have been reported by several researchers in different parts of the world example Alves et al (2010); Dar and Sundarapandian (2015); Ensslin et al (2015) but information on changes of woody species diversity, biomass and SOC stocks along the altitudinal gradient in HGAFs of Northern Ethiopia is lacking. Hence, this study was implemented with the objectives to determine the woody species diversity, structure, biomass and soil carbon stocks and to analyze the relationship between carbon stocks and woody species diversity in the different HGAFs of southern Tigray along an altitudinal gradient.

Materials and Methods

Description of the study area

The study area is geographically located between 12°54'36" N - 12°18'0" N latitude and 39°17'24" E - 39°44'24" E longitude with an altitude ranges from 1420–2603 m.a.s.l. on the Southern Tigray, Northern Ethiopia (Figure 1). The annual mean rainfall, mean monthly minimum and maximum temperature, dominant soil types and some of the soil physical and chemical properties of the study area (Table 1).

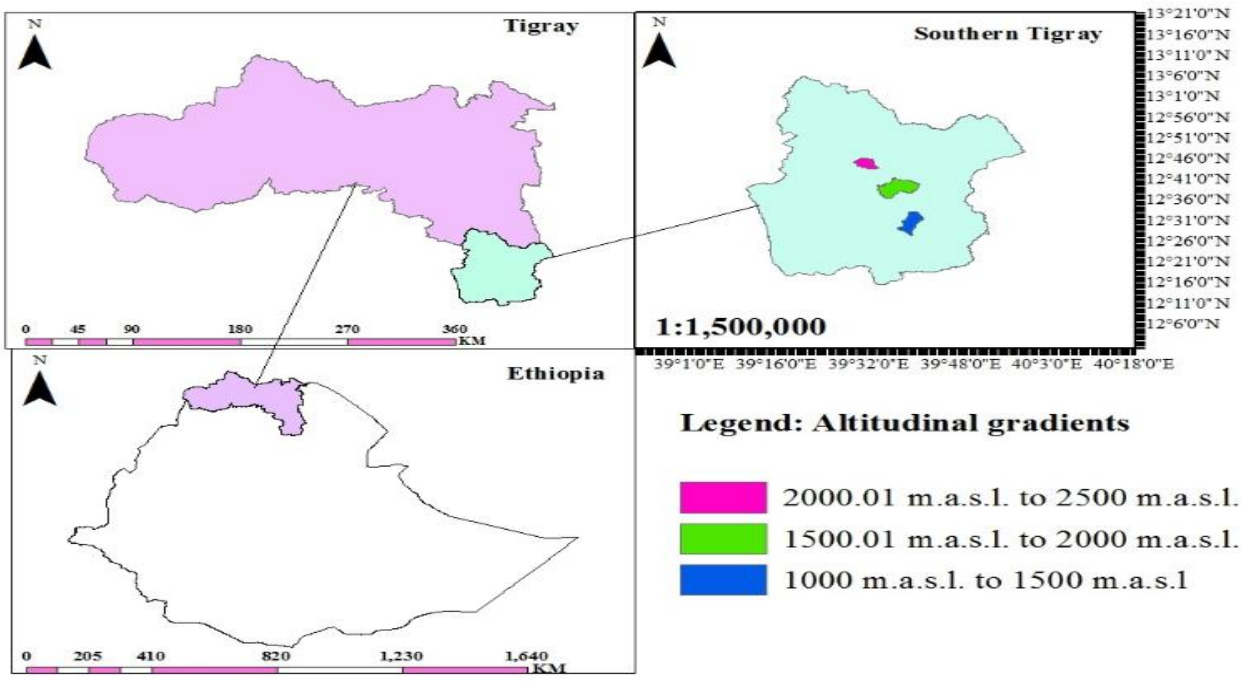

Figure 1: Location of the study area

Table 1. Climatic and soil physicochemical properties of the study area.

District	Ele. (m a.s.l)	Soil Type	P.mm Yr^{-1}	T. (^0C)	pH (1:2.5 KCI)	OC (%)	T N (%)	BD (g cm−3)
E/Mekoni	2000.01 to 2500	Eutric cambisol & Lithic leptosols	704.5	10.3 - 22.6	7.35	1.76	0.14	1.04
R/Azebo	1500.01 to 2000	Eutric vertisol & Lithic leptosols	513.1	12.9 - 24.5	7.45	1.82	0.14	1.09
R/Alamata	1000 to 1500	Eutric vertisol	700.2	14.2 - 29.4	8.03	1.99	0.15	1.09

Note: P.mm Yr^{-1} : annual average precipitation; T. ^0C :annual average temperature; OC: Organic carbon; TN: Total Nitrogen; BD: Bulk density.

Site selection and sampling design

Purposefully three altitudinal gradients highland, middle land, and the lowland were selected based on the presence of HGAFs. Age of the HGAFs and wealth status of the households (HHs) were considered to reduce its influence of woody species diversity and carbon stocks. For the selection of sample areas within home gardens, the back yard was taken. Inventory of woody species was taken from a plot of sample size 10mx20m Following. (Negash, et al 2011), visual estimation used to divide the homegarden into 10m x 20m ($200m^2$) equal parts. Second, a number was assigned to each part. Finally, the plot in which data collection took place was selected by generating random.

Data collection methods

Woody species inventory

Data were collected from a total of 33 plots comprising of 165 subplots i.e 55 subplots from each altitudinal gradients. Biometric parameters such as diameter at breast height (DBH) ≥ 2.5 cm and height ≥1.5m were measured and recorded in all sample plots. Trees forking below DBH were separately measured at breast height and the overall DBH of the forks determined as the square root of the sum of squares of individual stems (Snowdon et al 2002). Tree/shrub is defined as woody plants with DBH/DSH ≥ 2.5 cm and height ≥1.5m (Negash et al 2011). Specifically, trees are defined as a woody perennial plant with a single main stem or in case of coppice several stems and have a more or less definite crown. While shrubs are woody perennial plants, often without a definite crown, several stems growing from the same root.

The saplings and seedlings were counted within 2x2m ($4m^2$) sub-plots in the main plot, from the corners and at the middle one (Amberbr 2011); (Linger 2014). Saplings are young woody species with DBH < 2.5cm and height >1.5m whereas seedlings are woody plants with root collar diameter < 2.5 cm and height 20-1.5m. For identification of species in the field vernacular names using key informants and literature were used. The scientific nomenclature was carried out following to (Bekele-tesemma 2007; Ermias 2011)

Soil sampling and laboratory works

The soil samples were collected from every other plot which the vegetation sampling was conducted. It was collected within 1mx1m ($1m^2$) sub-plots in the plot, from the top left and bottom right corners and one in the middle. Two separate soil samples were collected for the analysis of SOC contents and soil bulk density. In each case, samples were collected from two depths of 0–30 and 30–60 cm layers. In one of the three subplots randomly selected, an undisturbed soil was taken through core sampling to determine bulk density using core sampler to determine the bulk density (MacDicken 1997). The soil samples for SOC analysis were collected using soil augur. Three soil samples were taken from the three $1m^2$ sub-plots of the plot and then for each depth composited differently into one from which representative soil sample was drawn (Schmitt-harsh et al 2012). The total number of soil samples from the different altitudinal gradients was 120 i.e. 60 for SOC and 60 for bulk density.

Method of data analysis

Estimation woody species richness, diversity, and evenness

All woody species above 20 cm height were considered for diversity analysis (Negash et al 2011). We calculated species richness (S), Shanon-Weiner diversity index (H), equitability/ evenness (J) and species dominance using Simpson dominance index (Cd) (Krebs 1985) and (Magurran 1988) using the following formulas.

Species richness (S) is calculated by.

Formula 1 $S = \sum n$

Where n is a number of species in a community.

Formula 2 $H' = -\sum_{i=1}^{s} Pi \ln(Pi).$

Where: H'= Shannon diversity indices; Pi= proportion of individuals found in the ith species.

Formula 3 $\textbf{Equitability (evenness)} J = \frac{H'}{H'max} = \frac{-\sum_{i=1}^{s} \text{Pi} \ln pi}{\ln s}$

Where S = the number of species; H'=, Shannon diversity indices and Pi = proportion of individuals found in the ith species.

Formula 4 $D = 1 - \sum_{i=1}^{S} pi^2$

Where D= Simpson's index of species diversity; S= number of species; Pi= proportion of total sample belonging to the ith species

The importance value index (IVI) for each woody species in the three altitudinal gradients **were calculated as follows:**

Formula 5

$$\text{Important Value index (IVI)} = \text{Relative dominance} + \text{Relative density} + \text{Relative frequency}$$

Biomass carbon stock

The above-ground biomass (AGB) of trees and shrubs were calculated using the plot inventory data and allometric model. Both species-specific and general allometric models were used to estimate the AGB (Table 2)

Table 2: Allometric equations used to estimate the aboveground biomass of woody species

Species	Allometric equation	R^2	Source
Olea europaea	$1.089*DBH^{1.684}$	0.94	Kebede & Soromessa (2018)
Coffea arabica	$0.147*D^2$	0.80	Negash et al (2013)
Eucalyptus species	0.085*DBH 2.471	0.95	Kuyah et al (2013)
Mangifera Indica	-2.43 + 0.154 DBH + 0.193 H	0.96	Chavan & Rasal (2012)
Balanites aegyptiaca and Acacia seya	$1.929 DBH + 0.116 (DBH)^2 + 0.013 (DBH)^3$	0.93	Mbow et al (2014)
Other species (general)	$0.1428*DBH^{2.2471}$	0.95	Kuyah et al (2014)

Note: DBH: Diameter at breast height (cm); d: is the diameter at stump height (DSH) at 40cm

The general model of Kuyah et al (2014) was adopted because it is established in Africa (Malawi) with a similar climatic condition to the study area. In addition, the model was developed using woody species from agroforestry practices and woodlands with 98% of trees having DBH of less than 40 cm which fits very well with the data from this study.

To convert the above-ground dry biomass to carbon, the default value of 50% (Formula 6) was used for trees and shrubs biomass was assumed to be the carbon stock (Kumar and Nair 2011). So based on the aboveground trees and shrubs biomass carbon stock calculated as follows

Formula 6 $\mathbf{AGC = AGB \ast 0.50}$

Where; AGC: Aboveground carbon stock for woody species (Kg/tree)

AGB: Aboveground biomass for woody species (Kg/tree)

Below ground dry biomass of the woody species (BGB) was determined as 27% of the above-ground biomass (IPCC 2003) and accordingly 50% for trees and shrubs were also adopted for its carbon estimation

Formula 7 and

Formula 8 respectively.

Formula 7 $\mathbf{BGB = AGB \ast 0.27}$

The carbon stock for a belowground component of trees and shrubs had measured as

Formula 8 below

Formula 8 $\mathbf{BGC = BGB \ast 0.50}$

Where; BGC: Belowground carbon stock for woody species (Kg/tree)

BGB: Belowground biomass for woody species (Kg/tree)

Therefore, the total biomass carbon stock for woody species (Formula 9) was calculated by summing above-and below-ground biomass carbon stock for woody species for each plot and the average of all plots has converted to hectare as follows:

Formula 9 $\mathrm{T\ BC\ (tone\ C\ ha^{-1}) = (Woody\ AGC\ + \ Woody\ BGC)}$

Where; T BC: Total biomass carbon stocks for woody species (tone ha-1)

AGC: Aboveground biomass carbon stocks for woody species (tone ha-1)

BGC: Belowground biomass carbon stocks for woody species (tone ha-1)

Soil analysis

The collected soil samples for soil bulk density analysis were initially air-dried and oven-dried at 105°C for 48 hours. The bulk density was calculated as the **Formula 10** below:

Formula 10 $\boldsymbol{\rho b}\ \left(\frac{\mathbf{g}}{\mathbf{cm3}}\right) = \frac{\boldsymbol{ODW}}{\mathbf{CV}-(\frac{\boldsymbol{RF}\ (\boldsymbol{g})}{\boldsymbol{PD}(\frac{\mathbf{g}}{\mathbf{cm3}})})}$

Where: ρ_b = Bulk density of the < 2mm fraction; ODW = Oven-dry mass of fine fraction (<2 mm); CV = Core volume; RF = Mass of coarse fragments (> 2 mm); PD = Density of rock fragments. This often is given as 2.65 g/cm^3.

The soil samples collected for analysis of SOC were air-dried, homogenized and ground sieved with a 2 mm mesh size sieve (Pearson et al 2007). SOC per plot and then per hectare was calculated as the Formula 11 below:

Formula 11 $\mathbf{SOC} = [(\ \boldsymbol{\rho b}\left(\frac{\boldsymbol{g}}{\boldsymbol{cm3}}\right) * \boldsymbol{D}\ (\boldsymbol{cm}) * \%\boldsymbol{C})]$

Where: SOC = Soil organic carbon [tone ha^{-1}]; % C = Organic carbon concentration of the plot [%] expressed in decimal; ρ_b = Bulk density of the plot [g/cm^3]; D = Depth of the soil sample [cm]. The SOC stock values for the two depths (0–30 cm and 30–60 cm) were summed to give the SOC stock for the total 0–60 cm depth.

Ecosystem carbon stocks

The total carbon stock of the along altitudinal gradient was calculated by summing total biomass carbon stock and soil organic carbon (0-60cm).

Statistical analysis

Prior to further statistical analysis, the normality of the distribution of data set was tested using the Shapiro-Wilk test if normality was not met, data were transformed in log values. F test and Leven's test was used to calculate the homogeneity of variance of the data. The difference between means was estimated by using a one way ANOVA, in case, data was not found homogenous Kruskal-Wallis test was used. The Spearman correlation coefficients correlation was used to analyze the relationship between woody species diversity and carbon stocks. The statistical analysis was done by using the R software program (R core team 2018).

Results and Discussion

Species area accumulation curve

The species-area curve of woody species of middle and higher altitudes flattened before the total numbers of samples were included in the analysis. However, in the lower altitudinal gradient, it was not flattened. The species-area curve shows that no new species were found after enumeration on 1800 m^2 (0.18 ha), for the middle and lower altitudes of HGAFs (Figure 2). Thus the sample plots were adequate for woody species analysis of middle and lower altitudes of the study area.

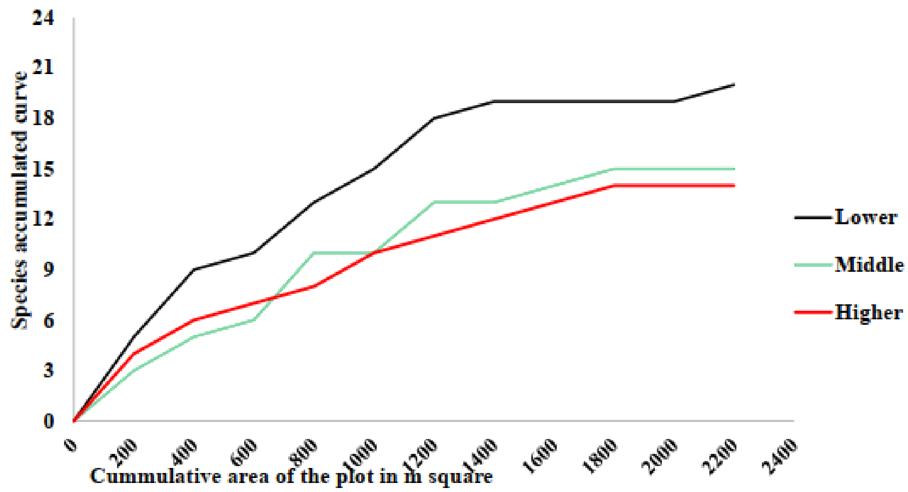

Figure 2: Species accumulation curve of woody plants in lower, middle and higher altitudes

Woody species composition

A total of 31 woody species representing 28 genera and 22 families were identified in the study area. Of which a high number of species, genera, and families were encountered in lower, middle and higher altitudinal gradients respectively (Table 3). The most important families in terms of tree species were Fabaceae (5 species), Rutaceae (4), Myrtaceae (3) and Cupressaceae (2). In the lower altitude of our study area up to 1500 m asl, many typical lowland tree families were Fabaceae and Myrtaceae, whereas at middle altitude Rutaceae and Myrtaceae and higher altitude Fabaceae, Myrtaceae Cupressaceae contributed the majority of species. Three woody species (*Catha edulis, Coffea Arabica,* and *Psidium guajava*) were common to all elevational gradients. The proportions of woody indigenous species were 58%, 50% and 50% in lower, middle and higher altitudinal gradients respectively.

Table 3: Species composition of HGAFs across the altitudinal gradient in southern Tigray

No.	Richness	Lower	Middle	Higher	Total
1	Species	19	16	14	31
2	Genera	18	14	11	24
3	Family	15	13	9	20

Woody species richness, diversity, and abundance

The overall values of Shannon diversity indices of woody species in the home gardens were estimated to be 2.38, 1.92 and 1.97 for lower, middle and higher altitudinal gradients respectively. Analysis of variance showed that tree species richness in the HGAFs decreased significantly with altitudinal gradients (Table 4). Our results reflect decreasing trends in woody species richness of HGAFs when moving from lower altitudes to higher altitudes. The low in species richness in the highland could be due to the high population pressure and hence selective cutting of the species and due to unfavorable topography for the species. Tree species richness decreased with altitude is in a similar manner as was found in other studies (Aiba and Kitayama 1999); (Homeier et al 2010) and (Slik et al 2009). However, not significantly different ($p>0.05$) was observed for abundance, Shannon diversity, evenness and Simpson's diversity (D) of woody species between the three altitudinal gradients.

Table 4: Analysis of variance for selected parameter across different elevations levels

Altitude	Richness	Abundance	Shannon diversity (H')	Simpson's diversity (D)	Evenness (H'/H_{max})
Lower	5.73(2.15)[a]	21 (11)[a]	1.31 (±0.46)[a]	0.62(0.18)[a]	0.76(0.16)[a]
Middlee	3.73(1.35)[b]	18(6.4)[a]	0.86 (0.41)[a]	0.46(0.21)[a]	0.66(0.21)[a]
Higher	4.27(1.95)[ab]	23(11)[a]	1.07 (0.42)[a]	0.56(0.17)[a]	0.77(0.18)[a]
P value	0.045	NS	NS	NS	NS

To evaluate the mean differences between altitudinal gradients Kruskal Wallis test was conducted. A similar letter shows no significant difference and different letters indicate significant differences at $p\leq0.05$.

Stand structure

There were significantly different ($p<0.05$) between altitudinal gradients in terms of diameter at breast height (DBH), height and basal area (Table 5)**Error! Reference source not found.**. At he community level, trees and shrubs had the smallest stem diameters, height and basal area in middle and higher altitudes. The lower woody species structure in the HGAFs may due to frequent thinning and pollarding practices. The HGAFs tree density of the study area was within the range of what was reported in the agroforestry system in southern Ethiopia (86 to 1082 trees ha^{-1}, Abebe 2013).

Table 5: Stand characteristics, mean (SD) of HGAFs across altitudinal gradient

Altitude	DBH (cm)	Height (m)	BA (m^2ha^{-1})	Density (stems ha^{-1})
Lower	12.51(8.33)^a	8.38 (3.43)^a	13.28(6.06)^a	1073
Middle	7.82(5.86)^b	4.66(2.67)^b	6.79(3.91)^b	909
Higher	7.87(5.1)^b	8.84(7.22)^a	5.01(4.18)^b	1150
P value	<0.001	<0.001	0.001	NS

Note: Different letters indicate significant differences between altitudinal gradients at p ≤0.05.

The diameter distribution of HGAFs in all altitudinal gradients concentrates in low DBH classes as shown in Figure 1 below. The result confirms that the number of individuals decreases as the DBH of the individual increase. This result is consistent with findings of other studies like (Suratman 2012); (Tefera et al 2014); (Tesfay et al 2019); (Tolera et al 2008) and (Yakob et al 2014). The overall community structure of HGAFs can help understand the status of regeneration. DBH class distribution of all individuals in different size classes shows an inverted J shape distribution, particularly in higher and lower altitudes (Figure 3).

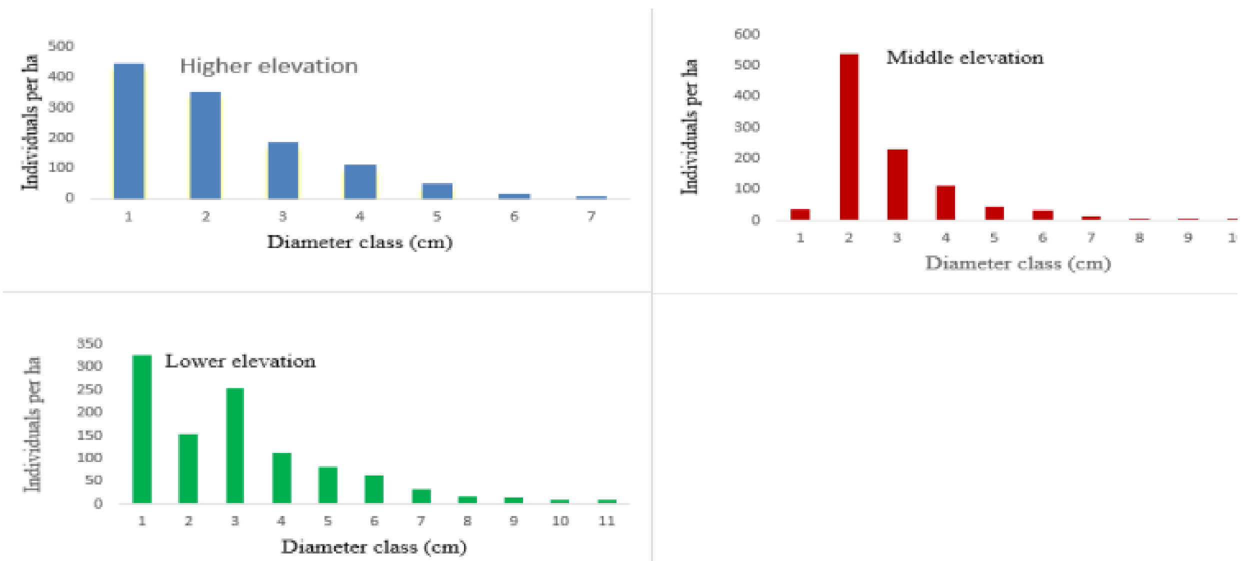

Figure 1: Diameter class (cm) distribution of woody species per hectare encountered in HGAFs across different altitudinal gradients: 1=<2.5, 2=2.50 - 6.49 cm, 3=26.50 - 10.49 cm, 4=10.50 - 14.49 cm, 5=14.50 - 18.49 cm, 6=18.50 - 22.49 cm, 7=22.50 - 26.49 cm, 8= 26.50 - 30.49 cm, 9=30.50 - 34.49 cm, 10= 34.50 - 38.49 cm, 11=50.50+ cm.

The general pattern shows the majority of species had the highest number of individuals (seedling/sapling) at relatively low DBH classes with a gradual decrease towards high DBH classes. This shows a healthier recruitment process and the population dynamics of the vegetation under study (Newton 2007). However, in middle altitude, it didn't show an inverted J shape.

Importance value index (IVI)

Species with high IVI are considered more important than those with low IVI. The result from IVI analysis showed that *Z. spina-christi* (56%), *Balanites aegyptiaca* (50%) and *Eucalyptus camaldulensis* (38%) were the top three important species in HGAFs of lower altitude. While in the Middle altitude HGAFs *Catha edulis* (70%), *Mangifera indica* (47%) and *Coffea arabica* (38%) and higher altitude *Olea europaea* (64%), *Eucalyptus globulus* (59%) and *Catha edulis* (58%) were high IVI value in the study area. These were recorded as abundant, frequent and dominant. This is likely due to their wider economic (Lamprecht 1989) and ecological roles (Neelo et al 2015).

The result is in line to other studies by Birhane et al (2006); Linger (2014); Tolera et al (2008); Yakob et al (2014) who reported the importance value gives a realistic value of dominance and the more dominant the species the higher is the important value of the species.IVI is also an important parameter that reveals for prioritizing species for conservation. Species with high IVI value require less priority for conservation effort while those with low IVI value need high conservation effort. The species having low IVI value should be prioritized for conservation (Zegeye et al 2005). Therefore the indigenous woody species in HGAFs of lower altitude (*E. cymosa and G. ferruginea*); middle altitude (*B. aegyptiaca, C. macrostachyus and D. angustifolia*); and higher altitude (*A. decurrens, C. myricoides, and D. abyssinica*) had low IVI (<10%) value hence need giving attention for conservation in the study area.

Biomass and soil carbon stocks

Biomass carbon stocks

The above- and belowground woody biomass carbon stocks were varied significantly ($p<0.05$) between the altitudinal gradients (Table 6). HGAFs of the lower altitudinal gradients contribute significantly higher above- and belowground woody biomass carbon stocks than the higher and middle latitudes. This study has shown that the aboveground biomass declines with increasing altitudinal gradients. It was in line with other studies in the world (Aiba and Kitayama 1999); (Kitayma and Aiba 2002); (Leuschner et al 2007); (Moser et al 2007) and (Waide et al 1998). The reason for the decline above ground biomass with increasing altitudinal gradients could be due to steep slope of the topography as a result soil supply of nutrients became progressively more limiting relative to plant demands at higher, cooler sites thereby limiting forest productivity and biomass accumulation (Kitayma & Aiba 2002) and (Raich et al 2006). In general decreasing the availability of nutrients, especially nitrogen, has been suggested to limit biomass stocks and tree height with increasing altitude (Grubb 1977).

Table 6: Mean biomass carbon stock in HGAFs across different altitudinal gradients (ton ha^{-1}).

Variables	Lower	Middle	Higher	P-value
AGCS	26.22(13.06) [a]	11.71(8.18) [b]	10.72(9.21) [b]	0.02
BGCS	7.21(3.64) [a]	3.17(2.2) [b]	3(2.6) [b]	0.02
T BCS	33.43(16.69) [a]	14.88(10.38) [b]	13.73 (11.8)[b]	0.02

Note: AGCS: Above-ground woody biomass carbon stocks, BGC: Below ground woody biomass carbon stocks: T BCS: Total biomass carbon stocks (Sum of AGCS and BGCS)

The carbon stored in the HGAFs of the altitudinal gradients were within the range of 12 - 228 tons C ha^{-1} reported for tropical agroforestry (Albrecht & Kandji 2003). Woody above- and belowground biomass carbon stock can be varied among HGAFs systems. The variation might come from the variation of the age of the trees, existing species, management of the forests and biophysical conditions. The use of an allometric equation for biomass estimation might also help to explain for the difference in estimated value as reliance on allometric equations could be one of the limitations resulting in large variations in such estimates (Alemu 2014).

Soil carbon stock

Soil carbon stock contents depend on topography, the type of soil, vegetation types and cover, climatic (temperature) and land management practices (Mwakisunga & Majule 2012). For instance, land management practices such as the removal of plant biomass and tillage can decrease C input from litterfall and root exudates (Li et al 2014). Besides, tillage reduces the physical protection of soil organic matter from decomposition because of the destruction of soil structure, which enhances the microbial decomposition of labile C (Johnson & Curtis 2001).

The soil organic carbon contents of the present study at different altitudinal gradients were varied significantly ($p<0.05$). It was significantly lower in the higher altitudinal gradients than the lower and middle altitudes. The finding with lower soil carbon stocks at highest altitudes are similar to those reported by Maitima et al (2009); Majule and Shishira (2008); Mwakisunga and Majule (2012) for soils found on slopes on Mount Kilimanjaro, Tukuyu in Mbeya and rungwe forest, southern highland of Tanzania respectively. The top surface layer accounted for 56%, 54% and 57% of the total SOC in HGAFs of lower, middle and higher altitudinal gradients respectively (Table 7). This pattern indicates that soil carbon decreased with soil depth exhibiting major trends in carbon accumulation in the upper soil. This corresponds to the depth with the greatest quantity of coarse and fine roots and litters.

Table 7: Mean soil organic carbon across a different altitudinal gradient (tons ha-1)

Variable	Depth (cm)	Lower	Middle	Higher	*P*-value
	0 - 30	58.24(23.35)[ab]	71.84(18.72)[a]	51.78(14.26)[b]	0.05
SOC ton ha^{-1}	30 - 60	46.58(20.45)[ab]	61.1(16.25)[a]	39.49(14.49)[b]	0.02
	Total(0-60)	104.82 (30.53)[ab]	132.94(30.53)[a]	91.27(26.13)[b]	0.016

Similar letters in the same row are not significantly different at ($p<0.05$).

Total carbon stock potential of the different pools

The total carbon stocks in HGAFs were 147.82 ± 31.76; 138.24 ±28.55 and 104.99 ± 27.42 tons ha^{-1} in middle, lower and higher altitudes respectively (Figure 4). The higher altitudinal gradient was significantly ($p < 0.05$) the lowest total amount of carbon stock. Soil organic carbon (0-60cm) contained the greatest amount of carbon followed by Woody AGC and BGC. This result is in line with the report about three times more carbon is contained in soils than in the global vegetation (Lal 2004) and (Post et al 2001).

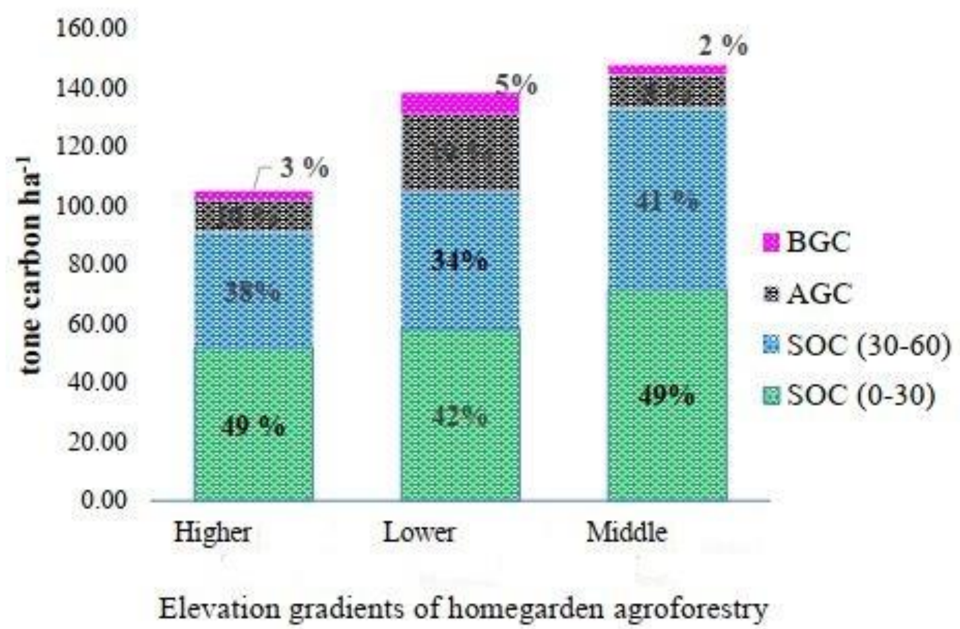

Figure 4. Biomass and soil carbon stock of HGAFs in different altitudinal gradients) in southern Tigrai

Relationship between woody species diversity, density, and carbon stocks

In all altitudinal gradients of HGAFs woody species diversity, richness and density were positively correlated with SOC, biomass, and ecosystem carbon tons ha^{-1} (Table 8). In HGAFs all altitudinal gradients density (trees per ha) were correlated positively and significantly ($p < 0.05$) with biomass carbon stocks. While in the higher altitude species richness with a biomass carbon stock and Shannon diversity which combines richness and abundance were correlated positively and significantly ($p < 0.05$) with SOC. This could be woody species with two or more species that may achieve higher levels of productivity than single-species plantations for a range of species combinations (Kelty 2006) and (Piotto 2008). Besides, if species mixes involve complementary resource use and/or facilitation of tree growth of one species by the other, with consequent positive impacts on belowground C sequestration through litterfall, root exudation and turnover or soil erosion control.

This was also similar with the positive and significant correlation between naturally regenerated plant species diversity and soil carbon concentration reported from lowlands of Tigray, Ethiopia by Mekuria et al (2009) and Similarly Saha et al (2009) found that species richness correlated to SOC in homegarden of Kerala; Species richness in agroforestry systems were positively correlated with above and belowground carbon stocks in South-eastern Rift Valley escarpment, Ethiopia Negash et al (2013); India. Mandal et al (2013) also reported a positive but very weak relationship between carbon stock and species richness Terai forest in Nepal. The general trend is that ecosystem with high biodiversity sequester more carbon in the soil than those which have lower diversity (Lal and Akinremi 1983).

Table 2. Spearman correlations of carbon stocks (ton ha-1) and woody species parameters

gradient	Carbon stocks		Biomass	SOC(0-60cm)	Ecosystem
Lower	H'	r	0.46	0.46	0.41
		p	0.15	0.14	0.21
	Spp r	r	0.48	0.41	0.36
		p	0.14	0.21	0.28
	Density	r	0.72	0.18	0.07
		p	0.01*	0.59	0.89
Middle	H'	r	0.03	0.45	0.43
		p	0.92	0.17	0.19
	Spp r	r	0.01	0.24	0.19
		p	0.97	0.49	0.57
	Density	r	0.78	0.18	0.07
		p	0.005	0.58	0.84
Higher	H'	r	0.53	0.08	0.018
		p	0.09	0.02*	0.96
	Spp r	r	0.68	0.26	0.09
		p	0.02*	0.44	0.8
	Density	r	0.78	-0.18	-0.07
		p	0.005*	0.58	0.84

Where, H'; Shannon diversity, Spp r: Species richness. * is significantly different at ($p<0.05$)

The positive correlations in HGAFs of biomass, SOC and ecosystem carbon stocks with woody species richness, diversity and density show that these components are important in storing soil organic carbon in addition to climate and age of HGAFs in the study area. These relationships suggest that the loss of biodiversity may damage the functioning of ecosystems and thus diminish the number and quality of services they provide such as carbon storage.

Conclusion and Recommendation

The variation in altitudinal gradients is one of the major determinant factors for woody species richness and carbon stocks on homegarden agroforestry systems (HGAFs) of southern Tigray. This is because with elevation tree species and composition tends to vary and they affect carbon stock contents. Homegardens in lower elevations maintained higher in woody species richness than the higher elevations. The total ecosystem carbon stocks of HGAFs in the higher elevation were also significantly lower than the middle and lower elevations. This study also revealed a positive relationship between carbon stocks and woody species diversity in all elevation gradients; this suggests that links between activities to conserve biological diversity and organic carbon may exist.

The promotions of homegarden agroforestry systems in the lower and middle elevations which support livelihoods and provide food is essential for conservation of high woody species and ensure climate change mitigation compared with higher elevations. Carbon emission reduction policy strategies such as REDD+ and CDM should recognize the potential HGAFs for their role in the mitigation of climate change and conserving biodiversity. More elaborate studies are needed with a larger number of homegardens at study locations with varying soil and agro-climatic conditions to explore the relationship between species diversity and C sequestration.

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3. Livestock Technology

Microbial Characterization, Prevalence and Associated Risk Factors of Cow Mastitis among Small Scale Farmers and Dairy Farms in Western Tigray, Northwest Ethiopia

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Abstract

A cross sectional study was carried out in Western Zone of Tigray, Ethiopia with the objectives to assess the management practice of dairy cows as well as to investigate prevalence of mastitis, associated risk factors, etiologies and their antimicrobial drug susceptibility test. In this study, out of the dairy cows and functional quarters examined, the prevalence of sub-clinical mastitis was found in 27.89% cows and 10.81% quarters. The frequency of cows with at least one blind quarter was found to be 24.79%. Moreover, 7.61% teats were found blind. The risk factors having statistically significant association ($P<0.05$) with prevalence to mastitis was found to be breed, udder type and parity. From 122 CMT positive quarter samples examined, 93.44% were found culture positive for one or more bacterial species. Higher resistance to penicillin (100%) and 50% susceptibility to Tetracycline was observed in case of *S. aureus*. In *S. epidermidis*, it was observed a 100% resistance to penicillin and 50% susceptibility to Chloroamphencole. Moreover, 100% resistance to Penicillin and Vancomycin was found in *E. coli*. With regard to cow management, 83.52% of the dairy owners housed their cows in open area with muddy floor and poor drainage. Furthermore, about 35.16% of respondents regularly dispose dung and clean the house. Majority (97.80%) milkers washed their hand prior to milking while 14.29% milkers disinfect their hands before proceeding to milk the next cow. Majority (93.41%) of milkers did not follow sequence of milking. Generally, results of the present study indicated that there was high prevalence of subclinical mastitis with higher incidence of one or more nonfunctional teat. Lack of strategic control measures and improper attention to the health of the mammary glands contribute to the higher infestation rate. Therefore, better management practices in milking and adequate housing with proper sanitation should be provided.

Keywords: California Mastitis Test; etiologies, drug susceptibility, teats, quarters

Introduction

Ethiopia is believed to have the largest livestock population in Africa (CSA 2009). Data from the estimation of CSA (2018) indicates that the country is a home for about 60.39 million cattle, 31.3 million sheep and 32.74 million goats, 11.2 million equines, 1.42 million camel, 56.1 million poultry with immense bee and fishery resources and Tigray region accounts for 4.82 million cattle, 2.47 million sheep, 4.3 million goats, 0.91 million equines, 0.43 million camel and 6.19 million poultry of the country.

Dairy production is one of the sectors of livestock production in many parts of Ethiopia (Yigrem et al 2008) and makes a major contribution to national and household economies. Milk obtained from dairy cows contributes significantly to meeting the human requirements for animal protein and is especially important in the diet of children and patients (Lukuyu et al 2012). Despite Ethiopia have large dairy cows population, the national and regional milk supply is low compared to its potential due to lower genetic potential, lack of market for animal and animal products, inefficient animal nutrient and different disease of animals in which mastitis is the disease among the fore mentioned constraints of dairy cow production (Yigrem et al 2008; Almaw et al 2009).

Mastitis is the most prevalent infectious disease of adult dairy cows and the infection is possibly developed when the cow is lactating or dries off (Andrews et al 2004). Mastitis disease can be classified as either subclinical or clinical, depending on how the severity of the infection, which in turn depends on how the cow able to resistant the infection (IDF 1987; Hillerton 1996). Mastitis is one of the most devastating diseases in the dairy industry (Halasa et al 2007; Hogeveen et al 2011). Mastitis cause a great deal of reduction in productivity, influence the quality and quantity of milk yield, cause culling of animals at an unacceptable age, distort animal welfare and also cause death of animals.

Most estimates have shown that subclinical mastitis cause 30% reduction in productivity per affected quarter and 15% reduction in production per cow throughout the lactation, making the disease one of the most costly and serious problems affecting the dairy industry worldwide (Bartlet 1991; Singh 1994; Rodistits and Blood 1994).

Although mastitis caused by more than twenty different groups infectious agents including bacteria, viruses, yeast, fungi and rickettsia, bacterial pathogens have the greatest share of that organism causing mastitis (Biffa et al 1999). The bacteria that cause mastitis in dairy cows classified into contagious and environmental bacteria. Contagious bacteria are those bacteria's which are carried on the mammary gland or teat skin and spread between quarters and cows at milking by the milking units or the hands of the milkers and may also be spread by inter-sucking between calves/heifers as well as flies as a vector. In the case of environment bacteria's bedding in the animal's house is the main reservoir and transferred to the teats from the environment when the cow lies down and also be transmitted between quarters and cows at milking to a lesser extent.

The most common contagious bacteria mentioned in the literature are *S. aureus*, *Streptococcus agalactiae,* and *Str. dysgalactiae* and environmental bacteria are coli forms (e.g. *E.coli* and Klebsiella spp.), *Str. uberis,* and Enterococci spp. Other bacteria of importance are including *S.epidermidis, Actinomycespyogenes, P.aeruginosa, Nocardiaasteroides, Clostridium perfringens*, Mycobacterium, Mycoplasma, Pasturella and Prototheca species and yeasts are included(Schalm 1971; Rodostits et al 2007; Nyman 2007)

Mastitis control relies upon the application of effective control measures to the herd rather than identification or special treatment of individual animals (Andrews et al 2004). Most new infections occur during the early part of the dry period and in the first two months of lactation, especially with the environmental pathogens. In heifers, the prevalence of the infection is often high in the last trimester of pregnancy and several days before parturition, followed by a marked decline after parturition (Radostits et al 2008)

Mastitis is a major disease in dairy cattle in Ethiopia and it was prioritized as one of major disease of dairy cows (Arga et al 2012). The incidence and distribution of the disease has not been studied systematically and information relating to economic loss, magnitude, distribution and risk factor of the disease is inadequate in Ethiopia and the study Tigray region. Therefore, the objective of the present study was to assess the management practice of dairy cows, to determine prevalence of bovine mastitis, associated risk factors, and etiologies as well as to conduct antimicrobial drug susceptibility test.

Material and Methods

Description of the study area

The study was carried out in Western Zone of Tigray Region, North West Ethiopia. It is one of the five administrative zones of Tigray regional state with one urban district and three rural districts. It is surrounded with Tahtay Adibayo, Tselemti and Asgede Tsimbla districts in the East, Sudan in West, Amhara region in South and Eritrea in the North and consists of three agro-ecological zones which comprised of 75% low land, 15.7% mid land and 9.3% high land. It is located at a distance of 580 to 750 km North West of Mekelle the capital city of Tigray and covers an area of 1.5 million hectare (HuARC 2013). The geographical location of the zone is at altitude 13°42′ to 14°28′ north and 36°23′ to 37°31′ east.

The minimum and maximum range of rainfall and temperature are 600 to 1800 mm and 27 0c to 45 0c in the lowland areas respectively whereas 100c to 220c temperature range both in midland and highland areas. The altitude of the zone ranges from 500 to 3008 m.a.s.l. and livestock production is the predominant economic activity with about 95% of the total population engaged directly or indirectly in it (Mekonnen et al 2011). Main cattle breeds raised are the local Arado (in both high land and mid land) and Begait cattle (in lowland). Semi-intensive production system is practiced in urban kebelle of the zone while extensive production system is dominant in all districts. The main crops cultivated in the lowland areas of the zone are Sesame, Cotton and Sorghum while Teff, Wheat, Barley, Noug, Lentils, Finger millet, Field peas and Faba beans are cultivated crops in both mid land and high land areas of the zone (Shishay et al 2015).

Study animals

The study animals that had been sampled were lactating smallholder dairy cows of different herds with different calving history. The study included 355 small holders lactating dairy cows which were indigenous local Arado (n=160), Begait breed (n=170) and cross breed (n=25) managed under the traditional extensive and semi intensive system of production.

Study design

A cross sectional study was carried out from November 2017 to June 2018. During the beginning of the study community identification and assessment was completed and list of study kebeles were done purposively based transport facility. The number of representative sample animals was proportionally allocated to the selected peasant associations based on the number of dairy cattle population and simple random sampling technique was used to select the study animals. Data related production system, risk factors, farmer knowledge about dairy cow mastitis and control was collected using semi- structured questionnaire format and screening test was conducted at the same time in nine kebelle of the study zone.

Sample size

Since there was no reasonable research in the study area so far, the expected prevalence was assumed to be 50%. The required sample size was determined based on the assumption of expected prevalence of 50% and by the formula given by Thrustfiled (2005) and the study was considering 95% confidence interval and 5% of absolute precision.

$$\frac{n = 1.96^2 Pexp\ (1 - Pexp)}{d^2}$$

Where, n= sample size

1.96= the value of Z at 95% confidence interval

Pexp= expected prevalence (50%)

d= desired absolute precision (5%)

Therefore, the calculated sample size was 384 samples due to various inconveniences 355 lactating dairy cows were taken.

Data collection

A semi-structured questionnaire format was developed and pre-tested, and all information relating to the study objectives was recorded. Age of the animals was determined from birth records and dentition characteristics and categorized as young adults (≤4 years), adults (>4 to ≤ 8 years) and old (>8 years). Stage of lactation was categorized as early (1–120 post-partum), middle lactation (121-240 days) and late lactation (greater than 240 days). Parity was also categorized as few (≤3 calves), moderate (3–5 calves) and many (≥5 calves) taken from (Fufa et al 2013) and Lidet et al 2013). The other risk factors were categorizes as ‘yes’ or ‘no’ for the presence or absence of the risk in the hypothesis respectively. Data regarding the different potential risk factors and management practice were collected from 355 lactating cows and by interviewing 91 animal owners

Screening test

Subclinical mastitis was diagnosed using California Mastitis Test (CMT) and the nature of coagulation and viscosity of the mixture was recorded. After physical examination and strict aseptic procedure followed a squirt of milk about 2ml was taken from each quarter of clinically free of mastitis lactating cows and was placed in each of four shallow in the CMT paddle and equal amount of Delaval California Mastitis Test (CMT) was added to each cup and a gentle circular motion was applied to the mixture for 15 sec. The results was read as negative (0), weak positive (+1), distinct positive (+2) and strong positive (+3). Reactions that included weak positive and above was considered as indicators of sub clinical mastitis according to (Quinn et al 1994).

Milk sample collection

Milk sample was collected by strict aseptic procedure to prevent contamination with microorganisms. Teat ends were cleaned and disinfected first using 70% ethyl alcohol before sampling. First jets milk was discarded to reduce the number of contamination of teat canal. Sterile universal bottle with tight fitting cups were used. The universal bottle was labeled with permanent marker before sampling. To reduce contamination of teat ends during sample collection, the near teats were sampled first and then followed by the far ones (Quinn *et al*., 1999). Then, 10ml milk sample was collected to the sterile universal bottle from CMT positive quarter, placed in racks for ease of handling and transported in ice box to Mekelle Regional Veterinary Laboratory and samples were stored at 4^{o}C until cultured for isolation.

Bacteriological isolation

Identification of mastitis causing pathogens was carried out following the standard procedures for diagnosis of bovine mastitis described by (Quinn et al 2004). According (NMC, 1990) bacteria may be concentrated in the cream layer of refrigerated milk sample and held within clumps of fat globules. Hence milk samples that had been refrigerated were warmed at room temperature (25^{0}c) for about an hour and shake it in order to made dispersion of bacteria and fat and the samples were allowed to stand for a while for the foam to disperse before inoculation. Loopful of milk sample was streaked on 7% sheep blood agar and plates were incubated aerobically at 37°C and the plates checked for growth after 24, 48 and up to 72 hrs to rule out slow growing bacteria pathogen.

The culture was considered negative if no growth occurs after 72 hrs. For the primary identification colony size, shape, color, hemolytic characteristics, pigment production, catalase production and oxidase test were conducted. Staphylococcus species were identified based on growth characteristics on Manitol salt agar, pigment production on blood agar, maltose fermentation and Coagulase test. Gram negative bacterial isolated that had been growth on MacConkey agar were identified to their species level by oxidase reaction, catalase test, Triple Sugar Iron (TSI), Urease test and the ″IMViC″ (indole, methyl red, vagesproskaur, and citrate test) (Quinn, 1999).

Antimicrobial sensitivity test

In vitro antibiotic sensitivity test was carried out on the most important mastitis causing bacteria's. Six antimicrobials agent such as Chloroamphinicol, Penicillin, Vancomycin, Tetracycline, Gentamycin and Ciprofloxacin were tested by Kirby-Baur disc diffusion method. A loop full of colony from the growth of isolates was transferred to the nutrient broth in tubes and incubated at 37°C for 5h. Mueller-Hinton agar which was used as plating medium was inoculated with broth (bacterial suspension) by using sterile cotton swab. Then antibiotic disks were applied and pressed onto the plate with forceps on the surface of the inoculated agar plates using aseptic technique. Plates were incubated at 37°C for 18h. The diameters of zones inhibition was measured and interpreted as sensitive, intermediate and resistant to different antibiotics according to national committee for clinical laboratory standard (NCCLS) (Quinn et al 2002).

Data analyses

The collected raw data was entered into Microsoft Excel data sheets and analyzed using STATA 11.1 statistical software. Descriptive statistics, percentages and 95% confidence intervals were used to summarize the proportion of infested and non-infested animals and the frequency of the questionnaire results also computed using this statistical software. The effects of different environmental and host risk factors were analyzed by Pearson chi-square ($\chi 2$) test. Statistical significance was set at $P< 0.05$.

Result and Discussion

Cow level prevalence of mastitis

The present study revealed that out of the total 355 dairy cows examined, a prevalence of 99(27.89%) was obtained (Table 1). The result of the present study is comparable with previous findings who reported a prevalence of 25.1% (Workineh et al 2002), 29% (Islam et al 2011) and 28.2% (Molalegne et al 2010).

Table 1. Total cows and quarter level prevalence of mastitis using California Mastitis Test

Quarter	Number of examined quarters	CMT positive quarters and cows	Positive (%)
RF	322	45	13.98
LF	339	27	7.96
RH	324	37	11.42
LH	329	33	10.03
Total quarter examined	1314	142	10.81
Total cows examined	355	99	27.89

RF, Right front; LF, Left front; RH, Right hind; LH, Left hind

On the other hand, it was lower than the 52.8%, 63.4%, 61.11% and 68.1% prevalence reported by Lidet et al (2013), Tolla (1996), Zerihun (1996) and Handera et al 2005), respectively. The result of the present study was also lower with report of (Sori et al 2005) who reported 52.78% prevalence in and around Sebeta, 53.25% prevalence in Dire Dawa town by (Biniam et al 2015) and 46.7% in Adama town by (Abera et al 2013). Moreover, the present results was less than the findings from other African countries such as 51.6% in Tanzania (Karimuribo et al 2009) and 51.8% in Rwanda by (Iraguha et al 2015) and 52% prevalence in Nigeria by (Salih et al 2011).

On the other hand, the result of the present finding is higher than the report of 10.6% prevalence in Tullo District West Hararghe by (Kasech et al 2016), 23.18 % by (Girma et al 2012) in Eastern part of Ethiopia and 19.14% prevalence reported by (Abdel-Rady and Mohammed Sayed 2009) in Egypt. Moreover, the report of the present finding is also by far higher than the report of (Belachew 2016) who reported5.3% prevalence and (Tesfaye 2007) reported 7.3% in Adama.

The variation in the prevalence of bovine mastitis in the report of different authors may be due to difference in used laboratory techniques, study design, climate and geographic difference of the study areas, the level of production and management practices, season of study, infestation of ticks, proportion of exotic gene inheritance and breed of animals studied.

Quarters level California mastitis test result

In this study, 142(10.81%) quarter level prevalence of subclinical mastitis was obtained (Table 1). The quarter level prevalence of the present finding is lower than the report of 21.94% (Shiferaw and Telila 2016) in and around Wolayta Sodo (Mekbib et al 2009, Nesru et al 1999 &Biffa et al 2005) who were reported 44.80%, 37% and 28.20%, respectively and 38.7% quarter level prevalence by (Adane et al 2012) from lactating cows of Boran breed from Yabello, Borana Zone whereas in line with report of (Girma et al 2012) and (Amdhun 2016) who reported 10.12% and 9.1% quarter level prevalence, respectively; and higher than the report of Belachew (2016) who found 6% quarter level positive in local indigenous breed around Debreziet.

According to the result of the present study, 45 (13.98%), 27 (7.96%), 37 (11.42%) and 33 (10.03%) Right front (RF), Left front (LF), Right hind (RH) and Left hind (LH) quarter position, respectively, prevalence was recorded (Table 1). As compared to the others quarters the right front (RF) quarters were affected with the highest infection rate. The Right hind (RH) quarter was the second followed by Left hind (LH) and Left front (LF) quarter.

The quarter wise prevalence of the present result disagree with the report of (Tripura *et al*, 2014) who reported 28.1% in Left Front (LF), 33.1% in Left Hind (LH), 24.5% in Right Front (RF), and 17.3% in Right Hind (RH) quarters which was higher in prevalence in Left Front (LF) and Left Hind (LH) quarter. Higher prevalence of subclinical mastitis in Right front (RF) and Right hind (RH) comparing to the other two quarter most probably due to the ease of grasping the right front quarters first while milking and the higher production capacity of hind quarters (Radostits et al 2007) and the chance of getting environmental and fecal contamination in the case of hind quarters (Sori et al 2005).

Incidence of cows with blind teats

This study revealed that 88(24.79%) cows were found with one or more teats blind and from the total 1420 quarter examined, 108(7.61%) quarters were also blinded and with highest incidence rate in RF and RH quarters (Table 2). The result of the present study is higher than (Girma et al 2012) and (Yien Deng et al 2015) who reported 2.2% and 0.21% quarters blind prevalence respectively. The result of the present study is closely agree with report of (Abera et al 2013) who reported 25 (9.4%) quarter prevalence in assella, Oromia region; but, slightly less than 33 (11.1%) reported by (Belachew 2016) around Debrezeit. Lack of screening subclinical mastitis and late or not treating clinical cases could possibly leads to blindness of mammary gland. Blind mammary quarters contribute to high subclinical mastitis and loss of milk production with a subsequent impact on food security (Sori et al 2005).

Table 2. Quarter level prevalence of blind teats

Blind quarter	No. examined quarters	Frequency of blind quarters	Positive (%)
RF	355	33	9.30
LF	355	16	4.11
RH	355	32	9.01
LH	355	27	7.61
Total	1420	108	7.32

Mastitis risk factors

The present result revealed that statistically significant association (P<05) in the prevalence of mastitis was found with breed, udder type and parity (Table 3). The result of this study indicated that higher prevalence of subclinical mastitis in cross breed dairy cows followed by Begait local dairy cows and lowest in local zebu breed. The result of the present study coincide with previous result obtained by (Sori et al 2005) who found higher prevalence of mastitis in cross breed cows than local breed and(Jirata and Indalem 2016) also reported a significant difference in the prevalence among zebu, jersey and high grade Holstein cows around Wolayta Sodo, Ethiopia.

Further (Nibret et al 2012) found a significantly higher prevalence rate in high grade Holstein-Friesian than Holstein indigenous zebu cross bred and indigenous zebu in Hawassa southern, Ethiopia. Breed influence on the prevalence of mastitis could be attributed to the difference in certain physiological and anatomical characteristics of the mammary glands such as capacity of milk production, teat structures, and udder conformation (Schutz 1993 and Radostits et al 1994). Large udder is easily injured and pus formed which create media for the multiplication of bacterial pathogens and in case of wide teat canal cows creates foci for the entrance of microorganisms as well as high milking cow affect by stress which may up set the defense mechanism of lactating dairy cows as described by (Radostits and Blood 1994).

Table 3. Association of subclinical mastitis prevalence to different categories of risk factors

Risk factors	Categories	Animal examined	Positive (%)	X2	p-value
Breed	Local	160	33(20.63%)		
	Cross breed	25	14(56%)	14.6377	0.001
	Begait	170	52(30.59%)		
Age	Young	44	11(25%)		
	Adult	227	62(27.31%)	0.6121	0.736
	Old	84	26(30.95%)		
Udder and teat lesion	present	13	4(30.77%)	0.0557	0.813
	Absent	342	95(27.87%)		
Lactation stage	1-120 day	110	34(30.91)		
	121-240 day	196	54(27.55%)	1.2311	0.540
	>240 day	49	11(22.45%)		
BCS	Poor	28	7(25%)	0.1819	0.913
	Good	282	80(28.37%)		
	Very good	45	12(26.67%)		
Parity	≤ 2 calving	181	45(24.86%)		
	3-4 calving	130	33(25.38%)	10.7617	0.029
	≥5 calving	44	21(47.73%)		
Udder Type	Pendulous	73	35(47.95%)	18.3846	0.000
	Non pendulous	282	64(27.70)		
Production system	Semi-intensive	41	12(29.27%)	0.0440	0.834
	extensive	314	87 (27.71%)		
Total prevalence		355	99(27.89%)		

High yielding cows have less efficacy of phagoacytic cells associated to dilution (Schalm 1971). The significant difference obtained between pendulous and non-pendulous udder structure in this study is, higher prevalence of mastitis in cows with pendulous udder could be explained by the fact that pendulous udder expose teat and udder to injury and the pathogens may easily adhere to the udder and teat getting access to inter the gland tissue (Grommers 1971 and Schalm 1971). Parity number also had significant influence ($P<0.05$) on the prevalence of mastitis in the present study. Highest prevalence was found in dairy cows' ≥5 calving followed 3-4 calving and lest in cows with ≤ 2 calves.

This finding is in agreement with report of (Fufa et al 2013 and Girma et al 2012) who recorded higher prevalence of mastitis in dairy cows wither highest parity number than lowest parity number. According to (Erskine 2001) primiparous cows have more effective defense mechanism than multiparous cows and multiparous cows affected by chronic sub-clinical mastitis especially by host-adapted pathogens such as *S. aureus* (Bradley 2002).

Bacteriological examination

With regard to the bacteriological isolation of the milk sample, out of 122 CMT positive sample used for bacteriological culture, 114(93.44%) sample were found culture positive for single or more bacterial species and 8(6.56 %) CMT positive collected milk samples were found culture negative (Table 4). The result of the present study is lower than the report of (Asefa et al 2017) who reported (9.2%) negative culture, (Mekibib et al 2010) who reported 15(10%) and (Sori et al 2005) who reported (9.82%) culture negative milk sample. The failure to isolate bacteria from the CMT positive milk samples could be associated with spontaneous elimination of the infection, low concentration of pathogen in milk, intermittent shedding of pathogen and intracellular location of pathogens and presence of inhibitory substance in milk (Radostitis 2000). It might also be due to some cases of delayed healing of the infection from which organisms may have disappeared or reduced, while infiltration of leukocytes continued until complete healing (Sori et al 2005) and death of the bacteria prior to culture due to delay of culture after the sample was collected (Zorah et al 1993).

Table 4. Proportion of cultured samples to positive culture

CMT positive quarter	Cultured sample	Positive culture	% positive culture
144	122	114	93.44

From the species of bacteria isolated *S. aureus* was the highest isolated which accounted 57(42.43%) of all isolate (Table 5). The finding of high level isolation rat of *S. aureus* in present lower than the report of (Lidet et al 2013) who found a prevalence of 54.4%*S. aureus* around Areka town, Southern Ethiopia and related with the finding (Lakew et al 2009) who reported 39.4%, (Sori*et.al*, 2005) who reported 44.03% in and Around Sebeta, Ethiopia.

The high prevalence of this organism may be associated with its frequent colonization of teats as they are commensals of the skin, its ability to intracellular persistence and localize within micro abscesses in the udder and hence resistant to antibiotic treatment (MacDonald 1997). The bacteria usually establish chronic, subclinical infections and are shed in the milk which serves as a source of infection for other healthy cows during the milking process (Radostitis 1994 and Molalegn et al 2010). Transmission among cows increase whenever there is lack of effective udder washing and drying, post- milking teat dip and drying, inter-cow hand-washing and disinfection, washing clothes and milking machine cups from infected quarters (Radostitis 1994). However, the incidences of the *S. epidermidis* are second predominate isolated bacterial species in this study with a relative prevalence of 47(33.07%) (Table 5).

The result of the present study is higher than the report of (Mekibib et al 2010) who reported 2(1.33%) (Sori et al 2005) reported 20 (14.93%) (Lidet et al 2013) reported a prevalence of 21 (8.4%) and (Fufa et al 2013) who reported 8 (11.27%) in Adis Abeba City Ethiopia but, lower than the report of (molalegne et al 2010) whore pot of 51.9 % in Bahir Dar and its environs Amhara, Region. The high isolation rate of *S. epidermidis* in this study could be associated with its characteristics of chronicity as all isolated were found from sub-clinical mastitis. The highest isolation rate of *S. epidermidis* from milk sample collected from bovine and other dairy animals which had mastitis, indicated that they could be pathogenic even causes more mastitis than *S. aureus* as reported by (Zeryehun et al 2013).

The third predominant bacterial species isolated in this study is *E.aerogen* with relative prevalence of 10 (7.46%) (Table 5). The finding of the present result is higher than the report of (Mekibib et al 2010) who reported 2(1.33) relative prevalence of *E.aerogen* in Dairy Farms of Holeta Town, Central Ethiopia. *E.coli* is the other coliform bacterial species isolated with 5

(3.73%) prevalence in this study which is in consent with the result of (Mekbib et al 2009 and Mekuria 1986 and Biffa 1994) who reported 4.60 %, 3.64% and 3.14%, respectively from different parts of Ethiopia and less than the report of (Amdhun et al 2016) who reported 47 (39.5%). *K.pneumonae* account 4 (2.99%) prevalence which is in agreement with report of (Girma et al 2012) who reported 3 (2.5%) in West Harerghe zone, Doba district and 3.30% infestation rate of (Mekbib et al 2009). *P.aerogenosa* 4 (2.99%) prevalence reported in this study also less than (Girma et al 2012) who reported relative prevalence of 5(4.1%) whereas proteus spp with 7 (5.22%) prevalence reported in this study higher than (Girma et al 2012 and Dinaol et al 2016) who reported 2 (2.7%) and 1 (1.9%) prevalence respectively (Table 5).

Characteristics of pathogens, environmental condition and level of management to risk factor which influence the prevalence of mastitis could be the reason for these differences in occurrence (Radostitis et al 2000).

Table 5. The relative rate of bacteria species isolated from bovine subclinical mastitis

Bacterial Species	Frequency (%)	Prevalence (%)
Staphylococcus aureus	57	42.43
Staphylococcus epidermidis	47	35.07
Proteusspp	7	5.22
Escherichia coli	5	3.73
Enterobacteraerogen	10	7.46
Klebsiellapneumonae	4	2.99
Psedomonasaerogenosa	4	2.99
Total	134	100

Antimicrobial sensitivity test

Of total isolated bacterial species, 38 isolate of three bacterial species were tested for susceptibility to six antimicrobial discs. In the current study, *S.aureus* is found susceptibility for Vancomycin (92%); Gentamycin (92%); Ciprofloxacin (83%) and Chloroamphinicol (83%) but, resistant for Penicillin (80%) and intermediate to tetracycline (50%). Susceptibility to Vancomycin (100%), Gentamycin (80%), Ciprofloxacin (100%), tetracycline (80%) and Chloroamphinicol (50%) was found in case of *S. epidermidis* (Table 6).

The report of the present result is similar with report of (Birhanu et al 2013) who reported *S.aureus* and *S.epidermidis* are more sensitive to Gentamycin (100%), Chloroamphencole (100%), and Vancomycin (100%). In the present study resistance to penicillin (100%) and intermediate to tetracycline (50%) in case of S.*aureus* and (80%) and (50%) resistance to penicillin and Chloroamphencole were obtained in *S.epidermidis*. *E.coli* is major mastitis causing microorganism and ubiquitous in the environment of dairy cows with manure is major source.

The antimicrobial susceptibility test of the organism in the present study is susceptible to Chloroamphencole (100%), Ciprofloxacin (100%), Gentamycin (75%) and tetracycline (75%) but, highly resistant to Penicillin (100%) and Vancomycin (100%) (Table 6).The highly resistance to those drug found in the present study is probably due to the indiscriminate and inappropriate doze use of those drugs by animal owners in the study zone, since the farms studied were mainly found in the rural area where veterinary services are not adequate, most farmers use treatment on their own as indicated by animal owners.

Table 6. Antimicrobial sensitivity test

Bacterial Isolates	N	C30		P10		CN10		VA30		CIP 5		Te30	
		S	R	S	R	S	R	S	R	S	R	S	R
S.aureus	24	20(83)	4(17)	4(20)	20(80)	22(92)	2(8)	22(92)	2(8)	24(83)	4(17)	12(50)	12(50)
S.epidermidis	10	5(50)	5(50)	2(20)	8(80)	8(80)	2(20)	10(100)	0(0.0)	10(100)	0(0)	8(80)	2(20)
E.coli	04	4(100)	0(0)	0(0)	4(100)	3(75)	1(2)	0(0)	4(100)	4(100)	0(0)	3(75)	1(25)

Management and hygienic practices

The survey was distributed to 87 (95.60%) males and 4 (4.40%) females household to collect information relating knowledge about mastitis and its management's practices. Out of the 91interviewee, 51 (56.4%) had elementary school's education, 10 (10.99%) of the farm owners were educated to high school level, 2 (2.20%) had college completed and the remaining 38(41.76%) were illiterates, indicated that there is a need of governmental interference to have all educated animal owner that had better know how about modern production system. During the management (housing, bedding, feeding etc.) and the degree of sanitation were assessed.

According the present survey results, 76(83.52%) of the dairy cows' owners housed their cows in open area, 2(2.20%) had simple enclosed area, 11(12.09%) had houses made of wooden and iron sheet and 2(2.20%) had houses made of brick and iron sheet. Similarly, as indicated by 82(90.11%) respondents the floor of the houses was earthy or soily floor type with 8(8.79%) had floor made of concrete and 1(1.10%) had floor made of stone and mud. Drainage condition of the houses were poor as indicated from 64(70.33%) respondents, 12(13.19%) had medium drainage condition and 15(16.48%) had good drainage. All the 91(100%) interviewed individuals had good ventilation. According to the responses of 32(35.16%) interviewed individuals regularly dispose dung and clean the animals' house but, the rest 59(64.84 %) of the dairy cows holders were not (Table 7).

Table 7. House condition and management of the farms

Questions	Possible Response	n	%
Housing condition of the farm? N=91	In open area	76	83.52
	Simply enclosed area	2	2.20
	Made of wooden and iron sheet	11	12.09
	Made brick and iron sheet	2	2.20
Floor type? N=91	Concrete	8	8.79
	Earthy floor muddy or soil	82	90.11
	Stone and mud	1	1.10
Drainage of house ? N=91	Good	15	16.48
	Medium	12	13.19
	Poor	64	70.33
Ventilation of house? N=91	Good	91	100
	Poor	0	0
Regular disposal of dung and cleaning of house? N=91	Yes	32	35.16
	No	59	64.84
Hygienic condition of the house? N=91	Good	12	13.19
	Medium	17	18.68
	Poor	62	68.13

According to the response of the respondent the sanitary condition of the house could be the cause for the highest occurrence of subclinical mastitis and blind teats in the local breed of cattle considered in this study as supported by (Biffa et al 2005) in semi-intensive and extensive dairy farms, cows were maintained in dirty and muddy common barns with bedding materials and manure that favor the proliferation and transmission of mastitis causing pathogens specially environmental pathogen.

In the study area, manual milking methods was practiced in the entire farm which was the major predisposing factors to increase the prevalence of mastitis in extensively managed local breed of cows (Table 8). Most of the milkers have little educational background and have limited knowledge about means of udder disease transmission.

Table 8. Udder management before and after milking

Questions	Possible Response	n	%
Hands washing before milking? N=91	Yes	89	97.8
	No	2	2.2
Washing hands with?N=91	With soap	40	43.96
	Without soap	48	52.75
	Sometime with both	1	1.1
	No washing	2	2.2
Inter cow hand washing? N=91	Yes	13	14.29
	No	78	85.71
Wash udder before milking? N=91	Yes	20	21.98
	No	71	78.02
With what do you wash the udder? N=91	No wash	71	78.02
	With tap and river water	18	19.78
	With boiled water	2	2.20
Do you use towel? N=91	Yes	90	98.9
	No	1	1.1
Do you follow Sequence of milking? N=91	Yes	6	6.59
	No	85	93.41
Do you milk cows with mastitis? N=91	Yes	18	19.78
	No	73	80.22
Milking cows with mastitis problem? N=91	No milk	73	80.22
	First	2	2.2
	No order	16	17.58

Concerning the implementation mastitis preventive measures, 89(97.80%) of the milkers often wash their hands with running and tap water prior to milking but, they did not disinfect their hands and teats between milking of different cows as reported by 78(85.71%) interviewed individuals, they did not use individual towel for drying of teats according response of 90(98.90%) and did not follow sequence of milking and has been milked the cow fist came as reported by 85(93.41%) individuals. During the survey, the condition of bovine mastitis and its management was assessed. Out of the 91 interviewed individuals, 84(92.31%) respondent had the knowledge on bovine mastitis and 7(7.69%) did not.

Regarding the occurrence of the disease in their farm, 83(91.21%) said it was occurring. All of the interviewed individual said tick infestation was always occur in their farm, with 50(54.95%) reported high infestation, 33(36.26%) reported moderately infestation and 8(8.79%) occur in slight infestation and most of them did not cull cows previously infected by mastitis (Table 9) and could be create an opportunity for the high distribution of subclinical mastitis and nonfunctional quarters in the study area. Injuries caused by ticks are known to cause direct inflammatory reaction to the mammary gland, necrosis, and abscess formation, which may lead to udder damage and/or exposure to serious secondary infections (FAO, 1998).

Table 9. Disease problem in the udder and its management

Questions	Possible Response	n	%
Have you heard about mastitis? N=91	Yes	84	92.31
	No	7	7.69
Have you observed case of mastitis in your farm? N=91	Yes	83	91.21
	No	8	8.79
What are you going to do if your cows have mastitis? N=91	Not treated	5	5.49
	Treat by them selves	42	43.39
	Take to vet clinic	32	35.16
	Traditional method	7	7.69
	Do not know about mastitis	7	7.69
Tick infestation in the farm? N=91	Yes	91	100
	No	0	0
Rate of infestation of tick? N=91	Highly infested	50	54.95
	Moderately infested	33	36.26
	Slightly infested	8	8.79
Method of treatment of ticks? N=91	Sprayed with chemical	71	78.02
	Traditional treatment	20	21.98
Have ever you culled mastitis cow previously? N=91	Yes	25	27.47
	No	66	72.53

Conclusion and Recommendations

The results of the present study indicated a relatively high prevalence of subclinical mastitis and with higher incidence of one or more nonfunctional teat. Best drug choice for treatment in the case of *S .aureus* were found to be Vancomycin, Gentamycin, Ciprofloxacin and Chloroamphinicol while Vancomycin, Gentamycin, Ciprofloxacin and tetracycline for S. epidermidis; and Chloroamphencole, Ciprofloxacin, Gentamycin and tetracycline for *E. coli.* .

On other hand higher resistance to penicillin (100%) and intermediate to tetracycline (50%) in case of S. *aureus,* penicillin and Chloroamphencole resistance was obtained in *S. epidermidis* whereas *E coli* 100% resistant to Penicillin and Vancomycin. Most of the respondent farmers are aware of the extent of the problem of bovine mastitis. Most of the dairy owners housed their cows in open area with earthy (muddy) or soily floor type, poor drainage and unhygienic condition with no regular disposal of feces and dung. Manual milking methods was practiced and have limited knowledge about means of udder disease transmission. Moreover, higher tick infestation occurs in the study area and culling of chronically mastitis infected cows was not practiced.

Based on the findings of the present study, it is recommended to design better mastitis management practice in milking and implement hygienic condition particularly washing milkers hand prior and between milking with clear water; follow sequence of milking; as well as adequate space in housing with proper sanitation. Moreover, avoiding indiscriminate use of antimicrobial therapies and regular antimicrobial susceptibility test of bacterial pathogen should be conducted. Training and extension services should also be launched by relevant authorities to animal owners on the issue of effective mastitis prevention and controlling measures.

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4. Agricultural Mechanization Technology

Observation Trial of Tractor Mounted Mechanical Precision Row Planter and Seed Drill Machine

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Abstract

The performance of a tractor mounted mechanical precision row planter and seed drill machine were evaluated for their suitability under the context of the target location in terms of reducing planting time without affecting yield and yield related parameter. The Performance of the seed drill and mechanical precision row planter machines were evaluated in Setit Humera district, western zone of Tigray, Ethiopia, on research station. The present results indicated that the mean values for time efficiency, actual field capacity and field efficiency for seed drill machine were found to be 68.60%, 1.27 ha/hr, 52.21%, respectively, while the values for mechanical precision row planter were 64.75%,1.59 ha/hr and 62.32%, respectively. The machines were found suitable for planting of sesame seeds in dry land.

Key words: Sesame seed, time efficiency, actual field capacity, field efficiency

Introduction

Ethiopia is one of the major sesame producing countries in the world, ranking 5th in production after Myanmar, India, China and the Sudan until 2010, according to FAO (FAOSTAT 2017). In Ethiopia, sesame is commonly cultivated in areas ranging in altitude from 500 to 1300 m above sea level in rain-fed condition. The low lands of Ethiopia adjoining the Sudan are the traditional sesame growing areas.

In Ethiopia, the production of sesame is both by small- and large-scale farmers; and it is an important crop and export commodity. The total area, production and productivity during 2013 were 0.299 million ha, 0.220 million tons and 0.735 t ha-1, respectively; and the total area and production were increased by 61.23 % and 17.91 %, respectively, while the total productivity was decreased by 27.23 % when compared with in 2008 (CSA 2008; 2013). Sesame ranks first in total area and production from oil crops during 2013; and Tigray, Oromia, Amhara and Benshangul Gumuz regions are the major producers in Ethiopia.

According Sesame Sector Development Strategy (Unpublished Working Document 2015), in the Northern west Tigray around Humera, land preparation for sesame production is done with tractors. Most of the operations in sesame production are done manually. Labor shortage is critical problem in the lowlands where sesame is grown and hence mechanizing the system is an urgent need to increase productivity and production and reduce the high pre- and post-harvest losses taking place currently.

Currently, different importers, namely ALT Engineering, Ultimate motors and Mamay group are importing to Ethiopia different type of planters. However, prior to introducing the machine to end users, it is mandatory to test and evaluate the performance of the machines as well as its feasibility under the context of the target location. Based on this concept, observation trial was carried out in collaboration with Humera Agricultural Research Center. Therefore, the present study was done to evaluate the performance of the imported tractor mounted mechanical precision row planter and seed drill machine in terms of time, field capacity, efficiency and yield.

Materials and Methods

Description of the study area

The experiment was carried out in Setit Humera, western zone of Tigray, Ethiopia, which is located at longitude and latitude 14°18′N 36°37′E, with an elevation of 585 metres (1,919 ft) above sea level and the Tekezé River runs to the west. Humera is the last important Ethiopian city south of the border with Eritrea and Sudan, and is considered to be a strategically important gateway to Sudan. The trial area was vertisol with high clay content and plain land.

Materials

The materials and instruments that were used for the field evaluation include tractor mounted precision row planters and seed drill machine; sesame seed; tape measure; stop watches and plastic containers.

Description and principles of its operation

The tractor mounted precision row planter machine and seed drill machine are presented in Fig 1 and 2. Details of the specifications of the tractor mounted precision row planter and seed drill machine are shown in Table 1.

Precision planters accurately place single seeds or groups of seed almost equidistant apart along a furrow. They are typically used to plant crops that require accurate control of plant population, and spacing between and along the rows. Precision seed metering systems giving a precision drill, hill drop or check row planting pattern are used on this type of planting machine.

Many of the crops requiring the use of precision planters are grown in wet season, are planted in wide rows and have individual seed boxes and associated seed meters for each row. Accordingly, precision planters are often referred to as wet season crop planters, row crop planters or unit planters.

The drill consists of a seed box, fertilizer box, seed and fertilizer metering mechanisms, seed tubes, furrow openers, seed and fertilizer rate adjusting lever and transport cum power transmitting wheel. The fluted rollers are driven by a shaft which gets power from wheels. Fluted rollers fixed in the seed box, receive the seeds into longitudinal grooves and drop them in the seed tube attached to the furrow openers. By shifting the rollers sideways, the length of the grooves exposed to the seed, can be increased or decreased and hence the amount of seed sown can be varied.

Figure 1: Mechanical Precision row planter Figure 2: Tractor mounted Seed drill machine

Table 1. Specification of the tractor mounted precision row planter and seed drill machine

Parameters	**Specifications**	
Model	Kappa Sofogia KAPPA SF 2500	Vence tudo SA 17700 A
Working width, mm	2500	3600
Total weight (Kg)	650	2130
Power source	Tractor 70hp and above	Tractor 75 hp and above
Hopper capacity		
Seed (liter)	275	217
Fertilizer (liter)	255	468

Source: Catalogue of the manufacturer

Calibration

In order to calibrate, the planter was held in the vice to free the drive wheels were removed. A paint mark was made on each of the drive wheels to serve as reference points to count the number of revolutions when turned; and a polythene bag was placed on each of the discharge spouts to collect the seeds discharged. The drive wheels were rotated 50 times at low speed as would be obtained on the field. A stop clock was used to measure the time taken to complete the revolutions. The seeds in each bag were weighed on a balance and the procedure was repeated five times. The machine was calibrated with the agronomic recommended 3 kg/ha sesame's seed rate, 150 Kg/ha fertilizer rate and 40 cm row space was adjusted, before the evaluation is under taken.

Field evaluation of the machines

The field performance evaluation of the machines was performed in June, 2018. The parameters measured included time, speed, effective field capacity, field efficiency, fuel consumption and yield. The sesame variety used was "Setit 2". The experimental plot was 200 m long and 40 m wide. The machines were powered by 4WD tractor with 130 HP.

Performance Parameters measured

Time taking for planting: The time taken for each trial when planting with machines was recorded. Time for each turn at the end of the plot, adjustments and removal of clogs when planting with the machines was also recorded.

Determination of operating speed: The operating speed was computed as follow

$$S\ (\mathrm{m/sec}) = \ L/t \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ Equation 1}$$

Where: S = operating speed, (m/sec), L = Length of the plot, (m) and t = time required to cover one pass, (sec).

Field capacity tests: The primary parameters used to evaluate the performance of the machines were the Field capacity (FC) (effective and theoretical) and field efficiency (FE) (ASABE 2008). While the area of land covered per unit time for a particular field operation was represented by FC, the ratio between theoretical and effective field capacities is defined as FE and relates to the actual and estimated time required to complete a particular field operation (with no reference to the area) (Viacheslav et al 2011).

Theoretical field capacity (TFC): The planter's theoretical field capacity (TFC) is dependent only on the average forward travel speed of the tractor in the field and its overall cutting width. It depicts the maximum possible field capacity that can be achieved at the specified field speed when the effective operating width of the machines is being utilized. It can be calculated from equation (2) (Hanna 2002).

$$\mathbf{TFC} = \frac{\text{Width of the drill}*\text{Average speed of the tractor}}{10} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ Equation 2}$$

Effective field capacity (EFC): This is the actual rate of performance of the planter in a given time, based upon the total field time.

$$\boldsymbol{EFC} = \ Testing\ plot\ in\ ha/(total\ time\ taken\ to\ drill\ the\ plot\ in\ hr) \ \ldots\ldots\ldots\ldots \text{ Equation 3}$$

A machine's TFC cannot be maintained over a very long periods of time. Therefore the machine's field efficiency (FE) is the ratio of effective or actual field capacity (EFC) to the theoretical TFC.

Field efficiency (η): Field efficiency is precisely the percentage of a machine's TFC which is achieved under prevailing real conditions. This accounts for the machine's failure to utilize its full operating width and inclusive of many other time delays. These might include turning, cleaning a plugged machine, idle travel across headlands, checking a machine's performance and making adjustments, etc. Other delays in activities that occur outside the field, such as daily service, movement to and from the field and major repairs, are not considered in field efficiency measurements (Hanna 2002). This can be calculated using equation 4.

$$\eta = EFC/TFC * 100 \ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 4}$$

Fuel consumption: Fuel consumption was measured by top up method. The tank is filled to full capacity before and after the test. Amount of refill is the fuel consumption for the test.

Result and Discussion

The field condition data for the performance tests conducted at Humera Agricultural Research center research field. The evaluation tests were conducted on a flat planting system.

Planting time

Table 2 shows the results of the time taken for planting with the machines to cover 0.8 ha for each planter. It was observed from the field test that planting with the seed drill machine consumed more time as compared to planting with a mechanical precision planter.

Table 2. Time taken for planting with the machines

	Machines	
	Seed drill machine	Mechanical Precision row planter
Total time taken to cover 0.8 ha in hr	37 min and 51 seconds	30 min and 11 seconds
Average total time taken to one pass (200m)	2 min 1 second 8 micro seconds	2 min 2 seconds
Average pass time (200m)	1 min 23 seconds	1 min 19 seconds
Average turning time (200m)	38 second 8 micro seconds	43 seconds

Operating speed

- Seed drill machine – 8.67 km/hr
- Mechanical Precision row planter – 9.11 km/hr

Field capacity

Table 3 shows capacitive performance and efficiencies of the planters. The theoretical field capacity at Seed drill machine and Mechanical Precision row planter were 2.43 ha/hr and 2.55 ha/hr respectively; effective field capacity at Seed drill machine and Mechanical Precision row planter were 1.59 ha/hr and 1.27 ha/hr respectively; field efficiency at Seed drill machine and Mechanical Precision row planter were 52.21% and 62.32% respectively. From the results it was observed that the both the theoretical field capacity and effective field capacity was recorded higher in mechanical Precision row planter. It was also observed that both the field efficiency higher mechanical Precision row planter. Even if the trial was affected by shortage of rainfall and pests, 360 kg/ha from seed drill machine and 315 kg/ha from mechanical precision row planter was harvested.

Table 3. Capacitive performance and efficiencies

	Machines	
	Seed drill machine	Mechanical Precision row planter
Theoretical field capacity (ha/hr)	2.43	2.55
Effective field capacity (ha/hr)	1.27	1.59
Field efficiency (**η**)	52.21	62.32
Fuel consumption (L/ha)	5.25	5.25
Yield (Kg/ha)	360	315

Conclusion and Recommendation

Performance of the seed drill and mechanical precision row planter machines were evaluated in the field and the average values for time efficiency, actual field capacity and field efficiency were found to be 68.60%, 1.27 ha/hr, 52.21%, respectively for seed drill machine and 64.75%,1.59 ha/hr and 62.32 % respectively for mechanical precision row planter. The fuel consumption was 5.25 liter per ha for drill and the row planter machines. Hence, those machines were found suitable for planting of sesame seeds in dry land. Even though the observation trial showed a promising result, before going to demonstration and scaling up, it requires a detailed future research in order to come up with reliable results. Moreover, the machines should also be tested using other crops grown in our region.

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