Tigray Agricultural Research Institute
Agricultural Growth Program-II

Adaptation and Generation of Agricultural Technologies


Proceedings of the Workshop held 09-15 November 2018, Capital Hotel, Wukro, Tigray, Ethiopia


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Acknowledgements

Tigray Agricultural Research Institute (TARI) have been contributing to the Program Development Objective (PDO) to increase agricultural productivity and commercialization of smallholder farmers targeted by the program and contributes to dietary diversity and consumption at household level. In achieving the PDO, TARI/AGP-II had approved a total 95 research activities in 2016, supported by the World Bank and to be implemented under technology generation, pre-extension demonstration and technology multiplication. The completed activities compiled here in this document are among the activities under pipeline up to the year 2016 and completed in 2017. These completed technology adaptation and generation works were presented and reviewed in the workshop, with the full participation of all relevant stakeholders, on November 9-15, 2018 and those accepted in the workshop are now edited and complied in this proceeding.

These achievements are brought by the relentless efforts of the young and senior researchers, the collaboration of the support staff and the research centers of TARI, development agents, the farming community, administrative bodies of the respective AGP-II mandate districts and the beneficiary farmers from the 205 AGP-II mandate *kebelles;* which are delighted to work with us and they deserve a great honor and gratitude for their contribution.

Desalegn Emuru
Research Component Coordinator
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Forward

The aim of the AGP-II Research Component is to adapt or generate agricultural technologies (subcomponent 1), undertake pre-extension demonstration of proven technologies to enhance adoption component 2), produce source technologies that would serve as a base for large scale technology multiplication (subcomponent 3) and enhance capacity of the research systems to improve technology supply (sub-component4). The technology adaptation, generation and pre-extension demonstration activities are envisaged to be implemented by taking into consideration principles of cross-cutting issues such as nutrition, gender and climate smart agriculture. The agricultural research component of AGP -II (Component 2) is composed of four sub-components:

a) Adaptation/generation of crop, livestock, soil and water management and farm implements technologies;
b) Pre-extension demonstration of agricultural technologies and establishment and facilitation of FREGs;
c) Production of early generation (breeder and pre-basic) seeds of food and forage crops, and animal breeds as source for wider technology multiplication by concerned actors;
d) And support to human and physical capacity development for enhanced technology supply by national research entities.

Cognizant of the importance of agricultural technologies, TARI has been undertaking s research in GTP-II period with the objective of adapting, generating and promoting agricultural technologies that enhance productivity and commercialization based on clustering , agroecology, and value chain approach and comprise the following strategy and approaches: **Technology Adaptation:** Introduction of appropriate technologies from local and abroad and adapt to Tigray condition ; t**echnology generation:** Development of own technologies; p**rescaling up and popularization** of promising technologies; and m**ultiplication and maintenance of source** technologies.

This proceedings which compiled technologies generated by TARI will serve as a reference for wider circulation and knowledge exchange among researchers, academicians, and development practitioners to fill gaps in technology delivery to enhance agricultural productivity and transformation of the agrarian landscape.

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Preface

The government of Ethiopia have brought the Agricultural growth program intended to increase agricultural productivity and commercialization of smallholder farmers and contributes to dietary diversity and consumption at household level. The project would also contribute to the higher-level objectives of poverty reduction and climate change mitigation and adaptation through supporting climate smart agricultural initiatives. To this end, the Tigray region is working on the five components of the program; Public Agricultural Support Services, Agricultural Research, Smallholder Irrigation Development, Agriculture Marketing and Value Chains, Project Management, Capacity Development, and Monitoring and Evaluation.

Tigray Agricultural Research Institute is therefore working on generating/adapting technologies suited to the agro-ecologies of the region and demonstrating them in close collaboration with farmer research and extension groups. TARI also supplies source technologies by multiplying them in the mandate areas on farmers field, to address problems related to seed shortage and the like. As part of the agricultural growth program, TARI had a total of 95 activities in 2016/17. So far TARI has supplied basic and pre-basic seed types of different food and feed crops. The sustainable supply of the technologies needs serious attention from the stakeholders working in the agricultural system. Technology generation demands alignment with the supply. Therefore, skill and financial capacity of seed producers need to be strengthened so that the technologies generated from the research will reach to large part of the farming community. Relevant stakeholders in the region and elsewhere should therefore take their share in capacitating seed producer groups and establishing seed cooperatives which should be aligned with commercial farms so that they will be linked to the agro-industrial parks.

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1. Crop Technologies

1.1. Evaluation and Registration of White-seeded Sesame Variety (*Sesamum indicum L.*).

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Abstract

Setit-3 (HuRC-4) is an adaptable, stable, high yielding (0.89 t/ha), high oil content (54.4%) with desirable traits as well as blight resistant variety. This variety was also selected by farmers during field evaluations for capsule number, number of branches, growth characteristics, number of seeds/capsule, logging characteristics, seed color, earliness, and diseases resistance. More over Setit-3 variety had about 18.25% and 34.25% yield advantage over the standard and local checks, respectively. Setit-3 (HuRC-4) was therefore registered and released as a variety for sesame growing areas of western zone of Tigray and similar agro-ecologies of Ethiopia.

Keywords*:* Setit-3, variety registration, *Sesamum indicum*.

Introduction

Sesame *(Sesamum indicum L.*) is the oldest self-pollinated annual oilseed originated that in Africa, Ethiopia and domesticated over 5000 years ago. It spread early through West Asia to India, China and Japan which became secondary distribution centers and now, it is cultivated in many parts of the world (Yamanura 2008). Sesame has been grown for over 7,500 years in Asia and Africa even in very poor growing conditions.

Sesame is a broad-leafed summer crop like cotton, sunflower, soybeans, black-eyed peas, or mungbeans. Sesame is an annual self-pollinating plant with an erect, pubescent, branching stem.

It is either single stemmed or branched with indeterminate and determinate growth habits and reaching up to 2 m in height. According to Kobayashi et al (1990), 36 species have been identified under the genus *Sesamum* with three cytogenetic groups 2n = 26, 2n = 32 and 2n = 64 and the widely cultivated *Sesamum indicum* is within the first group. The fruit of sesame is a capsule, often called pods. Some varieties have a single capsule per leaf axil while others have triple capsules. Flowering starts 35-45 days after planting and stops 75-85 days later. The seed is produced in the capsules and each capsule contains about 70 seeds (Langham et al 2010).

Sesame seed is often branded as Humera, Gonder and Wellega types, well known in the world market by their white color, sweet taste and aroma. The Humera and Gondar sesame seeds are suitable for bakery and confectionary purposes and the high oil content of the Wellega sesame seed gives a major advantage for edible oil production (Yamanura 2008). The major quality requirements of sesame seed exports are thousand seed weight (TSW), oil content and seed color. Thousand seed weight should be greater than 3 g, oil content of 40-50% and pearly-white seed color. White to golden color seeds are mainly used in raw-form because of their aesthetic value and are mostly priced higher than mixed seeds while yellow to dark brown seeds are generally crushed into oil (Wijnands et al 2007).

Though the volume of sesame produced by different countries is variable from year to year, Myanmar with productivity of 0.56 ton/ha was the leading one in 2012 main cropping season followed by India (0.34 ton/ha), China (1.31 ton/ha), Sudan (0.26 ton/ha) and Tanzania (0.67 ton/ha) (FAO STAT 2013). The average sesame productivity in Ethiopia in 2014/2015 main cropping season was about 0.7 ton/ha (CSA 2015) and was above the world average productivity of 0.51 ton/ha (FAOSTAT, 2014).

Ethiopian sesame is among the highest quality in the world, as seeds are produced at near-organic levels. Humera and Gonder types from the respective areas in particular are renowned for high quality and nutty aroma. Sesame production is therefore an important agribusiness sector in Ethiopia and is one of the six priority crops of the Agricultural Growth Programme (USAID 2012). Sesame accounts for 90% of the value of exported oilseeds, estimated at 379 million USD (FAOSTAT 2012) and 2nd only to coffee in foreign exchange earnings in Ethiopia (USIAD 2014). Sesame is also 2nd oil crop in terms of area coverage (420,494.87 ha) and total production (288770 ton/ha) next to noug (*Guizotia abyssinica Cass.*) (CSA 2015). The major sesame regions in Ethiopia are Tigray (western and north western 36%), Oromia (East Welega 17%), Benishangul Gumuz (Belles valley 15%) and Amhara (Metema 31%) are the most sesame producing regions in the country (Adefris et al 2011).

Western Tigray is among the major sesame producers in the country where most of the production is directed to national and international markets (HuARC 2018), though the average yield of sesame in western zone of Tigray is very low (<0.5t/ha). The reasons for low productivity include improper agronomic practices and unavailability of varieties resistant to biotic and abiotic stresses. So high yielding, adaptable, pest tolerant varieties with good plant characteristics and high demand for export are needed in western zone of Tigray. Humera Agricultural Research Center (HuARC) is therefore conducting different research activities in collaboration with regional, national and international research centers and universities to solve sesame production constraints. So far four white-seeded sesame varieties demanded by the export market (Setit-1, Humera-1, setit-2 and Setit-3) and suitable for western zone of Tigray and similar agro-ecology of Ethiopia were developed and released for use by beneficiaries (investors and small scale farmers) (HuARC, 2018).

Material and Methods

The experiment was conducted at six locations in northern Ethiopia; Humera, Dansha, Sheraro, may-kadra, Wargiba (Alamata) and Gendawuha (Metema) and at two farmers fields in each location (Table 1). Three promising candidate genotypes (HuRC-4, HuRC-3 and Landrace gumero (candidate) were compared with Setit-2 (standard check) and Hirhir (local check) during the 2016 growing season. Each plot had a total area of 100 m^2 (10 m x10 m), with inter and intra row spacing of 40 cm and 10 cm, respectively, and 23 harvestable rows. The experimental plots were ploughed two times (first time before sowing and second during sowing) to maintain fine seedbed suitable for sesame establishment. Each experimental plot received the same rate of (100 kg/ha) DAP and 50 kg/ha Urea (split application) fertilizer. All field management practices were done equally and properly as per the recommendations to the study areas. Phenological data viz. days to emergence, flowering, maturity, plant height, number of branches, number of capsules per plant, length of capsule bearing zone and yield/ha was recorded along with oil content.

Table 1. Description of the study areas.

Descriptor	Humera	Dansha	Banat	Maykadra	Sheraro	Gendawuha
Altitude (m)	606	773	593	707	1006	760
Latitude	1419388	1355139	1378043	1387835	142400	12^o
Longitude	3676001	3696491	3639773	3662495	375600	36^o
Temperature (^{0}c)	18.8-37.6	28	28	28	13.3-40.5	19.5-35.7
Soil type	Chromic Vertisol	Vertisol	Chromic Vertisol	Chromic Vertisol	Vertisol	Vertisol
RF (mm)	576.4	888.4	NA	NA	1000	850-1100

Result and Discussion

White-seeded sesame varieties performance evaluation

The adaptation trial of 17 sesame genotypes was conducted at Humera, Dansha, Sheraro, Wargiba, Maykadra, and Gendawuha from 2014-2015 main cropping seasons and were evaluated for yield, yield components, oil content as well as their pest and disease reaction. There was significant difference among the varieties across years and locations for mean yield (Table 2), with mean yield of the tested varieties across years and locations ranged from 0.44 t/ha to 0.867 t/ha.

Three best adapted genotypes with the highest mean yield, oil content and other agronomic characteristics (HuRC-4), Landrace gumero and HuRC-3 were identified as candidate varieties and were evaluated during 2016 main season by comparing them with standard and local checks (setit-2 and Hirhir) at six locations and two farmers field in each test station; Humera, Dansha, Sheraro, Banat, Rawyan and Adebay. Each plots had a total area of 100 m^2 (10 m x 10 m) with inter and intra row spacing of 40 and 10 cms, respectively. Each experimental plot received the same rate of DAP and Urea fertilizer. Pesticides and all field management practices were applied according to the recommendations. The national technical variety evaluating committee were invited and found that Setit-3 (HuRC-4) had good field performance and was high yielder, early maturing and blight tolerant as compared with the standard and local checks. The national variety release committee, considering field performance report from the technical committee, farmer's preference and their 10 environment combined report, selected Setit-3 (HuRC-4) to be released as variety in 2017.

Table 2. Analysis of variance result of the white-seeded sesame varieties at six locations

Sources of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	2	245131	122565	15.57	<.001
Location	5	4210695	842139	107.01	<.001
Genotype	5	839921	167984	21.35	<.001
Year	1	1491662	1491662	189.54	<.001
Location.Genotype	20	815788	40789	5.18	<.001
Location.year	3	8849898	2949966	374.85	<.001
Genotype.year	5	386684	77337	9.83	<.001
Location.Genotype.year	12	461660	38472	4.89	<.001
Residual	102	802712	7870		
Total	155	18104151	116801		

Agronomic and morphological characters

Setit-3 (HuRC-4) variety has a pearly white seed color, ovoid seed shape, medium seed size, good thousand seed weight (2.9 g), erect growth characteristics, extra early maturity and had a height of 99.02 cm. Agronomic and morphological characteristics of the released variety summarized and presented in Appendix table 1 and Table 3, respectively.

Table 3. Yield and yield components of white-seeded sesame varieties across years and locations

Varieties	DM	NCPC	NCPP	NBBP	LCBZ	TSW	SY	% Oil content
HuRC-3	89.8	27.73	27.73	3.12	52.89	2.7	792.5	50.35
HuRC-4	76.9	37.25	37.25	3.21	54.5	3.11	867.4	54.4
Landrace gumero	85.73	31.43	31.43	3.63	51.4	2.85	753.8	50.1
Local check	80.1	32.03	32.03	3.44	52.44	2.92	645.5	49.95
Standard check	80.83	30.5	30.5	3.21	49.97	2.94	745.1	50.3
Grand mean	82.672	31.79	31.79	3.32	52.24	2.9	760.85	50.14
LSD (5%)	**	**	**	*	*	*	**	**
CV%	3.2	10.5	8.9	20.5	10	14.1	15.1	28

Mean yield performance the tested varieties

Setit-3 (HuRC-4) was one of the collected 100 land races from northern Ethiopia and has passed different sesame breeding stages from 2014 to 2016 main cropping seasons. This variety was also evaluated against checks for mean yield and oil content across locations and years. The mean yield of this variety was 0.11 t/ha at research station and 0.89 t/ha at farmers field in the verification trial. Similarly recently released varieties Obsa and Dicho gave yields ranging from 0.106 to 0.868.8 t/ha at farm level (Dagnachew et al 2011). Moreover Setit-3 (HuRC-4) had about 18.25% and 34.25% yield advantage over the standard and local checks, respectively. The average productivity of sesame in many farmers and investors in the Humera area is less than 0.5 t/ha and the low productivity was due to poor agronomic practices, no use of improved varieties and other biotic and abiotic constraints. This variety, besides to good yield, is very early and is therefore recommended for moisture stress areas in western zone of Tigray.

Diseases reaction

Sesame webworm and seed bug are the major insect pests of sesame while blight and phyllody are major diseases, yet this variety has recorded the lowest blight score of 3.8 during the evaluation as compared with the standard (4) and local checks (4.1 on a score of 1-9), respectively.

Yield stability across years and locations

The stability analyses were conducted for 17 collected sesame land races genotypes using Eberhart and Russell's Linear Regression Model (1966) across two years and six locations. According to coefficient of regression analysis and estimated value, setit-3 variety is the most stable with its mean seed yield and oil content than others. Setit-3 is considered adaptable and good mean yield performance at an altitude of 650 (Humera) to 1500 meters (Wargiba and Metema). This finding is therefore in agreement with that of Gemechu and Bulcha (1992) and Demissie et al (1992) who reported that the best agro-ecology for sesame adaptation and wider genetic diversity is an altitude below 1500 meters.

Conclusion and Recommendation

Setit-3 (HuRC-4) is a high yielding sesame variety very well adapted to western Tigray. It has high oil content besides being blight resistant. Setit-3 is liked and selected by the farmers. Moreover Setit-3 variety has demonstrated significant advantages over the standard and local checks, respectively. Setit-3 is released and registered as variety for commercial production in western zone of Tigray as well as similar agro-ecologies of Ethiopia.

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Appendix

Table 1. Adaptation zones, agronomic and morphological characteristics of Setit-3 variety.

1. Variety name	Setit-3 (HuRC-4)
2. Adaptation areas	Humera, Dansha, Banat, Sheraro, Metema, Alamata, Adebay, Rawyan, Maykadra
3. Adaptation agro ecology	
• Altitude (m.a.s.l)	600-1500
• Rainfall (mm)	563-888
• Temperature	18.8-37(C^o)
4. Recommended Agronomic practices (Fertilizer rate + other practices	
• DAP (kg/ha)	100
• Urea (kg/ha)	50
• Planting date	Mid June to mid-July
• Planting depth (cm)	99.02
• Seed rate (kg/ha)	0.8-1.2
• Distance b/n rows and plants	40 cm x 5 cm
5. Morphological and other yield components	
• Days to flowering	41
• Days to Maturity	75-80
• Seed color	Pearly white
• Capsule number/plant	37.25
• Number of seeds/plant	69
• Yield (qt/ha)	
◦ Research field	9-12
◦ Farmers field	9-11
• oil content	54.4(%)
• crop pest reaction	relatively tolerant insect pests

1.2. Drought Tolerant Sesame (*Sesamum indicum L.*) Variety Setit-2 (*J-03)* and its Packages

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Abstract

This paper is meant to share information about the high yielding sesame variety Setit-2 (J-O3) to all beneficiaries including farmers, investors, researchers and extension experts. Setit-2 is an adaptable, stable, high yielding and high oil content sesame variety with other desirable traits. It is also blight and drought tolerant variety. Farmers also selected Setit-2 in field evaluation for the following traits: capsule number, number of branches, growth characteristics, number of seeds/capsule, seed color, and earliness. More over Setit-2 variety has 39.59% and 51.51% yield advantage over the standard and local checks, respectively. Setit-2 is released during 2016 main season and registered as variety for commercial production for western, north western Tigray as well as similar agroecologies of Ethiopia.

Keywords*:* Setit-2, variety, *Sesame indicum* L.

Introduction

Sesame (*Sesamum indicum L.)* belongs to family Pedaliaceae. It is an important and ancient oil crop. It has an edible seed and has high quality oil (Pathak et al 2014). In Ethiopia sesame is known as Selit in Tigrigna and Amharic languages (Seegler 1983). Sesame is grown for local consumption and export in Ethiopia. It ranks first in area of production among oilseed crops grown in the country (CSA 2015). Ethiopia is among the world's top five producers of sesame and third largest world exporter of the crop (Zerihun 2012). Sesame production is increasing from year to year, which is mainly driven by increasingly high export market demand and availability of suitable agro-ecologies (Arshad 2003).

Despite its nutritional and high market value oil crop, research on sesame has been limited and still it is produced under traditional management practices in developing countries. Yield of sesame is highly variable dependent upon the growing environment, cultural practices and cultivar (Brigham 1985). The major constraints in sesame production are lack of widely adapted cultivars, shattering of capsules at maturity, non-synchronous maturity, poor stand establishment, lack of fertilizer responses and low management practices (Ashri 1994). In the case of Ethiopia lack of improved varieties, seed supply and extension services for producers are main problems (Sorsa 2009).

In Ethiopia, a 28% reduction in production of sesame is due to insect and diseases (Minot and Sawyer 2013). Among the many insect pests affecting sesame production worldwide sesame seed bug (*Elasmolomus sordidus*), sesame webworm (*Antigastra catalaunalis*), termites, gall midge (*Asphondilia sesami*), green vegetable bug (*Nezara viridula*), African bollworm (*Helicoverpa armigera*) and jassids (*Orosius albicinctus*) have been recorded in Ethiopia.

Sesame seeds are highly valued for their high content of sesame oil, oil that is very resistant to rancidity. Sesame seeds are the main ingredients in tahini and the Middle Eastern sweet treat, halvah. Open sesame -the famous phrase from the Arabian Nights reflects the distinguishing feature of the sesame seed pod, which bursts open when it reaches maturity (Anon 2017). Sesame oil has desirable physiological effects, including antioxidant activity, and blood pressure and serum lipid lowering potential (Zhang et al 2013). Sesame oil has high content of flavored linoleic acid ($C_{18}H_{32}O_2$) and a particular feature is that it contains an antioxidant which prolongs the shelf-life of both the oil and other foods fried in the oil (Gooding et al 2000).

Sesame has wide range of applications (Wijnands et al 2007). The most important ones are edible oil that is odorless with distinctive nutty sweet flavor. Roasted sesame seed resists rancidity due to the antioxidants formed during seed roasting. Sesame oil is especially important in the far eastern countries mainly Japan and China for confectionery, biscuit and bakery industry. Hulled clear white sesame is required for bakery products and Tahini and Halva industry. Tahini is a traditional Middle Eastern paste made from hulled sesame seed and is rich in protein. Halva is a sweet made of 50% Tahini, boiled sugar and some other ingredients. Sesame flour and sesame seed sprouts are also used as pharmaceutical ingredients.

North western and Western Tigray are the most suitable area for agricultural investment and commercialization. They are suitable for different crops such as sesame, cotton, sorghum, mungbean and other low land crops meant for the agro-processing and export sectors. Farmers and investors want market preferred, adaptable and stress tolerant sesame variety. Sesame produced in northern Ethiopia white, production methods are organic and is very important for different processing purposes. The Humera agricultural research center was therefore conducting different sesame research activities to develop high yielding and stable sesame variety that meet market demands.

Materials and Methods

Adaptation and performance evaluation of Setit-2 during 2014/2015

The experiment was conducted in 2014/15 cropping season under rainfed condition in six environments that comprises two testing locations for three years with sixteen sesame genotypes. The sesame genotypes were sown in a randomized complete block design (RCBD) with three replications in a plot area of 14 m^2, each experimental plot received the same rate of DAP (100 kg/ha) and urea (50 kg/ha) and all other agronomic practices were applied as per the recommendation for the crop in the respective testing locations. Homogeneity of residual variances was tested prior to a combined analysis over locations in each year as well as over locations and years (for the combined data) using Bartlet's test (Steel and Torrie 1980). Bartlet's test showed data were homogenous and all data followed normal distribution.

Results and Discussion

Sesame genotype *Setit-2* was the highest yielding genotype (913 kg/ha) followed by J-01 (703.6 kg/ha). *Setit-2* has a yield advantage of 56.8% over the standard check and had also scored highest number of pods per plant and even number of seeds per pod. Furthermore, in terms of the most important agronomic traits (earliness) in drought prone areas, *Setit-2* was among the early maturing genotypes with only 84 days required for maturity. Earliness combined with the other important agronomic traits, led the genotype to variety verification trial (Table1).

Table1. Combined yield and yield components for sesame genotypes during 2013-2015.

Genotype	BPP*	DF*	DM*	PH (cm)*	PPP*	SPP*	Yield (kg/ha)*
G-02	2.2b-f	43.8ab	89a	118.8ab	20.4de	66.3ab	665.1[bc]
Abasena	2.9abc	44.5ab	88.8a	119.1ab	23.8b-e	50.1e	582.1[bcd]
J-02	1.7def	43.6ab	87.7ab	111.8ab	21.4cde	63.73abc	645.1[bc]
J-03	1.7ef	41.2ab	84bcd	123.4ab	34.7ab	69.2a	913.0[a]
J-01	1.8def	46.3a	87.4abc	127.4ab	25.2b-e	60.6bcd	703.6[b]
Unknown sel-1	1.6f	43.2ab	86.6abc	107.6b	19.9e	54.4de	530.3[cd]
Acc-00048	3.156ab	45.6a	86.4abc	132.9a	31.9a-d	55.2de	576.7[bcd]
ACC-205-191	1.9c-f	40.4ab	86.2a-d	115.2ab	32.2abc	58.2bcd	678.6[b]
SPS-SIK-98-2	2.3a-f	44.7ab	86.1a-d	125.3ab	23.1cde	58.3bcd	651.0[bc]
B-02	2.8abc	43.5ab	85.8a-d	116.7ab	19.9e	59.2bcd	597.3[bcd]
Acc-203-630	1.7def	45.7a	85.7a-d	128.8ab	20e	61.2bcd	569.2[bcd]
Unknown Kaja-sel-4	2.5a-e	41ab	84.8bcd	117ab	27.6b-e	66.3ab	664.3[bc]
Margo selection	2.1c-f	44.2ab	84.1bcd	127.2ab	28.5b-e	60.5bcd	684.1[b]
Bcs-043	2.7a-d	45.1a	87.6ab	123.6ab	23.4b-e	61.03bcd	674.9[b]
Acc-111-848	2.7abc	38.3b	83.5cd	117.3ab	27.2b-e	56.03cde	667.6[b]
Kenya	3.2a	45.1a	82.4d	125.7ab	39.6a	63.8abc	497.2[d]
Mean	2.34	43.56	86.06	121.1	26.24	60.27	643.8
LSD (5%)	0.817	5.47	3.2	18	9.7	6.8	182.4
CV (%)	37	13.5	4.1	16	29	12	27.3

*, Means in columns followed by the same letter are not significantly different at α=0.05. BPP, branches per plant; DF, days to flowering; DM, Days to maturity; PPP, pods per plant; PH, plant height; SPP, seeds per pod.

Setit-2 verification during 2016 main season

Three promising genotypes Setit-2 (candidate), Setit-1 (standard check) and Hirhir as local check were tested during the 2016 growing season at six locations. In the study each plot had a total area of 100 m^2 (10 m x 10 m), keeping inter and intra-row spacing of 40 cm and 10 cm, respectively. Each plot had a total of twenty five rows and twenty three harvestable rows. The experimental plots were ploughed two times (first time before sowing and second during sowing) to maintain fine seedbed suitable for sesame establishment. Each experimental plot received the same rate of DAP (100 kg/ha) and Urea (50 kg/ha) fertilizer (applied in splits), chemicals and all other field management practices were done equally and properly as per the recommendations to the study areas. Data on days to emergence, flowering, maturity, plant height, number of branches, number of capsules per plant, length of capsule bearing zone and yield/ha were recorded and oil content was also analyzed.

The candidate genotype Setit-2 was also evaluated by the variety technical committee in the variety verification trial together with the standard and local checks planted at six locations and six different farmers' fields. The candidate genotype Jsetit-2 demonstrated its superb performance in earliness and grain yield. The candidate genotype setit-2 was by far better than the local and standard checks (Table 2). The variety technical committee from the ministry of agriculture evaluated the genotypes at farmer's field level by collecting samples of different agronomic data and farmers preferences. The technical committee therefore recommended to the national variety release committee that setit-2 be registered and released. Upon recommendations from the technical committee, the national variety release committee finally decided that setit-2 be registered and released for production in the Western and North Western of Tigray and similar agro-ecologies of sesame growing areas in Ethiopia.

Setit-2 is a white seed color, ovoid seed shape, medium seed size, good thousand seed weight (3 g), erect growth characteristics, early maturity and 100 cm plant height presented in table 2. Moreover Setit-2 has 39.59% and 51.51% yield advantage over the standard and local checks, respectively. The average productivity of sesame in many farmers and investors in the study is less than 0.5 t/ha.This low productivity is due to lack of improved varieties and other production constraints. This variety is very early, drought and diseases tolerant variety released for moisture stress areas in western and north western Tigray. Setit-2 is best adapted and gives good yield at an altitude of 650 (Humera) to 1500 meters altitude (Sheraro and Metema). Several workers have reported that the best agro-ecology for sesame adaptation and wider genetic diversity is at altitude below 1500 meters altitude (Gemechu and Bulcha 1992; Demissie et al 1992).

Table 2. Yield, yield components and phenological data for sesame genotypes in the variety verification trial in six locations

Treatments	DM	BPP	PH	SC @ Harvest	LPBZ	PPP	Yield (kg/ha)	Yield advantage (%)
J-03 (candidate-1)	78	1.8	128	1326	79.4	27	11	
Setit-1(standard check)	82	2.8	116	1240	70.2	33	788	39.59
Hirhir (local check)	84	3	123	1098	65.8	25	726	51.51
Bcs-043 (candidate-2)	98	2.2	96	1140	37.8	10	412	

Setit-2 variety pest reaction

Web worm, gall fly, seed bug, mealy bug and termite are the major sesame insects while blight, wilt, phyllody are major sesame diseases in the study area. This variety has recorded lowest blight score (3.1) during the evaluation as compared with the standard (3.9) and local cheeks (4.1), respectively.

Agronomic and morphological characteristics of Setit-2

Table 3. Adaptation areas, recommended agronomic practices, morphological, yield and other characteristics of Setit-2 variety.

Variety name	Setit-2(J-03)
1. Adaptation areas	Humera, Dansha, Banat, Sheraro, Metema, Maykadra
2. Adaptation agro ecology	
➢ Altitude (m.a.s.l)	600-1500
➢ Rainfall (mm)	563-888
➢ Temperature	18.8-37(C^{o})
3. Recommended agronomic practices (Fertilizer rate + other practices	
➢ DAP (kg/ha)	100
➢ Urea (kg/ha)	50
➢ Planting date	Mid June to mid-July
➢ Planting depth (cm)	3.5
➢ Plant height (cm)	100
➢ Seed rate (kg/ha)	0.8-1.2
➢ Distance b/n raws and plants	40 cmx10 cm
4. Morphological and other yield components	
➢ Days to flowering	45
➢ Days to Maturity	80-87
➢ Seed color	white
➢ Capsules number/plant	37
➢ Number of seeds/plant	60-300
➢ Yield (qt/ha)	
• Research field	9-11
• Farmers field	8-11
➢ oil content	54(%)
➢ crop pest reaction	relatively tolerant insect pests
5. Year of release	2016
6. breeder/maintainer	Humera ARC/ TARI

Conclusion and Recommendation

Setit-2 is stable, adaptable and high yielding and high oil content sesame variety with good desirable traits like blight and drought tolerance. Setit-2 variety recorded highest yield performance during adaptation and verification trials. This variety is selected by the farmers. More over Setit-2 variety has shown significant yield advantage over the checks. Setit-2 is released in 2016 and registered for commercial production in western, north western Tigray as well as similar agro ecologies of Ethiopia.

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1.3. Effects of Inter and Intra-row Spacing on Yield and Yield Attributes of Tomato *(Lycopersicon esculentum Mill) in* North Western Zones of Tigray

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Abstract

A field experiment was conducted to study the effect of different inter and intra-row spacing on the growth and yield of tomato in Northwestern Zone of Tigray during 2014-2016 cropping season under irrigation condition. The objective was to determine the best inter and intra-row spacing for optimum yield and yield components of tomato. Treatments consisted of factorial combination of four inter-row spacings (60, 80, 100 and 120 cm) and four intra-row spacings (20, 30, 40 and 40 cm) using Randomized Complete Block Design with three replications. The highest marketable fruit yield was obtained from 20 cm intra-row and 60 cm inter-row spacing. On the other hand, the lowest marketable fruit yield was obtained from 50 cm intra-row and 120 cm inter-row spacing. The present result indicates that determinate tomato types can produce higher marketable fruit yield under narrowly spaced plants. From this study it could be concluded that appropriate inter and intra-row spacing, dependent on the type of variety, could be practiced to increase the yield of tomato. Thus, growers around the study area can benefit if they use narrow spacing of 20 cm intra and 60 cm inter-row spacing on the melkasalsa variety of tomato.

Keywords: tomato, spacing, yield.

Introduction

Tomato (*Lycopersicon esculentum* mill) is a nutritious and popular vegetable all over the world. Tomato ranks third, next to potatoes and sweet potatoes, in terms of global vegetable production. In Ethiopia tomato is also among the most widely grown vegetable crops. Its production has shown a marked increase and it has became the most profitable crop providing a higher income to small scale farmers compared to other vegetables (Lemma Dessalegne et al 1992). However, the national average tomato yield of 9 t/ha in Ethiopia is quite low compared to other African countries like Kenya (16.4 t/ha). The majority of tomato growers do not produce high enough because lack of knowledge regarding improved management (Tesfaye 2008).

The national average fruit yield under farmers' condition (9 t/ha) is also very low compared to the yield obtained at research plots (25-40 t/ha) (Lemma et al 1992). Increasing tomato production will also strengthen the growing agro-industry in the country. However, the production and productivity of tomato in the country is influenced by different factors. Lemma et al (1992) for example reported that plant spacing greatly influenced fruit yield for the fresh market and processing tomatoes. The importance of plant spacing on yield and quality parameters in tomato crop is reported (Mehla et al 2000). Yield variation in tomato may also occur due to disease infestation, lack of improved variety and variation in cultural practices like plant population per given area but plant spacing is the most important factor that affects yield and fruit quality of tomato (Tesfaye 2008).

In Ethiopia, plant spacing on tomatoes was determined only at Melkasa agricultural research center. Information generated from this center may not represent all tomato growing agro-ecological zones in the region and especially no such study was done in tomatoes under vertisol condition and the whole of such previous agronomic studies were confined only to sandy loam soils of the rift valley regions of the country. Tomato growers in the rift valley regions can directly use the recommendation from this research center but this same recommendation cannot apply for the other tomato growing regions with completely different agro-ecology.

Spacing requirement of tomato depends on soil type and its inherent fertility (Lemma et al 1992) and the type of cultivars (Mehla et al 2000). Blanket recommendation would be inappropriate and therefore there is an urgent need to identify appropriate recommendation for specific soil types and cultivars grown in the region. Thus, the present investigation was proposed with an objective to determine the best inter and intra-row spacing for optimum yield and yield components of tomato in north western zone of Tigray.

Materials and Methods

The experiment was conducted during 2015--2017 under irrigation condition in Northwestern Zone of Tigray, at the Shire-Maitsebri Agricultural Research Center (SMARC) experimental

Stations. The experiment was a 4x4 factorial in Randomized Complete Block Design (RCBD) with three replications. The two factors consists of 4 different inter-row (60, 80, 100 and 120 cm) and four different intra-row spacings (20, 30, 40 & 50 cms). Each plot had five rows and different number of plants per row (15, 10, 8 and 6 plants for 20, 30, 40 & 50 cm intra row spacing's, respectively). The tomato variety used was Melkasalsa and seedlings were raised in nursery for about 30 days. Finally, seedlings were translated and planted at the predetermined inter and intra-row spacings. All management practices for the crop were applied uniformly as per the recommendation for the nursery and field conditions.

Method of data collection

All data relating to yield and yield components were collected from the central three rows by excluding plants from either end of the rows. For the purpose of data collection 6 plants per plot were selected randomly and relevant data on the growth, yield and yield components of the test crop (plant height, fruit diameter, fruit weight, fruit length, number of fruits/plant, fruit yield/plant, marketable yield) were recorded periodically.

For recording plant height, 6 sample plants per plot were measured from the ground level to the top at the end of mid stage of the crop using a ruler. Days to 50% flowering were taken when half of the plant population on the net plot area sets flower. Days to physiological maturity are the number of days from transplanting to maturity stage. Fruit number/plant was determined by counting the number of fruits of each plant at each harvesting time from 6 randomly selected plants from each plot. Diameter of 10 randomly selected ripened fruit was measured using caliper from each plot and length of 10 randomly selected ripened fruit were measured using caliper from each plot. Fruit weight of 10 randomly selected ripened fruit was measured using a sensitive balance from each plot. Finally, weight of healthy and marketable fruit yield per plant was weighted from six tagged plants with in the plot from six times harvest. For total fruit yield (Qt ha^{-1}), weight of healthy and marketable fruit yield per plot was determined and converted to Qt ha^{-1}.

Method of data analysis

All crop data collected in this study were subjected to two way analysis of variance following a procedure appropriate to randomized complete block design (Gomez and Gomez 1984). When the treatment effects were significant, least significance differences (LSD) test was used to separate the means.

Results and Discussion

Marketable fruit yield of tomato

The analysis of variance revealed that the interaction of intra and intra-row spacing had significant effect ($p<0.05$) on marketable fruit yields of tomato (Table 1). The highest marketable fruit yield (37632Kg/ha) was obtained from the combination of 60 cm inter-row and 20 cm intra-row spacing. However, the lowest marketable fruit yield (22867Kg/ha) was recorded at wider spacing of 100 cm inter-row and 40 cm intra-row spacing. The highest marketable yield recorded at closer spacing is attributed to more tomato fruit produced from more number of tomato plants per hectare. The higher marketable yield at narrow plant spacing could be due to greater canopy and growth habit of determinate tomato type tomato variety like Melkasalsa. Hence, unmarketable fruit yield is minimized than the plants planted at wider spacing. This result is in line with Lemma et al (2006) who reported the highest marketable pepper pod yield at Bako (20.09 qt /ha) and at Didesa (15.57 qt/ha) planted at closer spacing of 20 cm between plants.

Number of fruits per plant

Significant effects ($p\leq0.05$) of inter-row spacing were observed for number of fruit/plant (Table 2). The wider spacing (120 cm) had the highest fruit per plant (56.98) and the lower inter-row spacing (60cm) had lowest number of fruits per plant (43.75). This result indicates that increased plant spacing led to increased in number of fruits per plant.

Table 1. Interaction effect of inter and intra-row spacing on tomato marketable fruit yield.

Inter-row spacing (cm)	Intra-row spacing (cm)	Marketable fruit yield(kg/ha)
60	20	37632a
60	30	35168ab
60	40	31008ab
60	50	27064ab
80	20	31934ab
80	30	30975ab
80	40	27675ab
80	50	25519ab
100	20	28957ab
100	30	28999ab
100	40	26849ab
100	50	22867b
120	20	29069ab
120	30	27221ab
120	40	24937ab
120	50	23609ab
	LSD	7678.4
	CV (%)	33.1

Table 2. Means for inter row spacing effect on marketable fruit yield, number of fruits and fruit yield per plant

Inter row spacing (cm)	Yield and yield parameters		
	Number of fruits per plant	Marketable fruit yield (kg/ha)	Average fruit weight (gm)
60	43.76c	32718a	45.10
80	49.38b	29026ab	46.07
100	51.66ab	26918b	46.94
120	56.98a	26209b	46.37
LSD	5.58	3796.4	Ns
CV (%)	27.5	32.8	16.6

Average fruit weight

As shown in Table 2, there was no significant effect of inter-row spacing on fruit weight. This finding is therefore in variance with previous works of Muhammad and Singh (2007) who reported higher tomato fruit weight from wider intra-row spacings.

Conclusion and Recommendation

Tomato is the most important vegetable crop in Ethiopia, providing a higher income to small-scale farmers compared to other vegetable crops. However, tomato production is constrained by several factors. Farmers in the study area get lower yields mainly due to disease, pests, inappropriate agronomic practice and lack of improved seeds. Improper plant spacing is among the notable reason for low productivity of tomato. This study was conducted to investigate the effect of different inter and intra row spacings on growth and development of the tomato under irrigated conditions. It was carried out under North western zone of Tigray at Shire-Maitsebri Agricultural Research Center experimental station during 2015/2016.

The results of the present study showed that number of fruits/plant and marketable fruit yield were significantly affected by inter and intra-row spacing of tomato. The maximum marketable yield of tomato was obtained at 60 x 20 cm inter and inter-row spacing. It is, therefore, concluded that spacing of 60 x 20 cm can be recommended for tomato growers in the study area as the marketable fruit yield was high compare to the other treatments. Moreover further investigations might be needed on different soil types, quality aspects together with other agronomic management practices to identify best technology for improving productivity of tomato.

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1.4. Adaptation of Onion Varieties in North Western Zone of Tigray

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Abstract

Field experiment was conducted to study the effect different onion (*Allium cepa* L.) varieties on yield, yield components in Tselemti district, north western Zone of Tigray during 2015-2017 irrigation seasons. Four improved onion varieties (Bombey red, Adama red, Nasik red & Nafis) along with Shendi (from Sudan) were tested in Randomized Complete Block Design (RCBD) with four replications. Five varieties (treatments) were assigned randomly to the experimental plots within a block. The results showed that variety had significant effect on all characters except neck thickness and bulb diameter. Nasik red had thehighest plant height, leaf number, leaf length, bulb length and marketable bulb yield. Nasik red gave marketable bulb yield of 35588 kg/ha and had a yield advantage of 18% and 36% over Bombey red and Adama red, respectively. The overall study revealed that growing Nasik red will significantly increase the marketable bulb yield in the study area. Nasik red is therefore recommended for Tselemti district so that farmers reap profits from onion production.

Keywords: Onion, nasik red, yield

Introduction

Onion (*Allium cepa L.*) belongs to the genus *Allium* of the family *Alliaceae* (Hanelt 1990). Onion, one of the oldest vegetables known to man, is the most important bulb crop cultivated commercially in nearly most parts of the world. It originated in the region covering the near east and central Asia. Onion was known to Egyptians, Romans and Greeks, who initially used it as a medicinal plant, before it becomes a condiment or a vegetable (Lannoy 2001).

Onion (*Allium cepa* L.) is a recently introduced bulb crop into the agricultural commodities of Ethiopia that is rapidly becoming a popular vegetable among producers and consumers (Lemma and Shimeles 2003; Dawit et al 2004). In Ethiopia, onion is more widely grown for local consumption and flower export (Lemma and Shimeles 2003).

Onion is now contributing substantially to the national economy. Besides to the local demand, the bulbs and cut flowers are exported to different countries of the world. Cut flower is for example exported to European countries. There is good potential to increase the exports of fresh fruits and vegetables to the neighboring countries such as Djibouti, Sudan and Somalia. In these countries there is a strong demand for products such as chilies, onions, cabbages, bananas, mangoes, etc. Ethiopia will therefore have a big potential to benefit from export of onion. In view of this, onion is one of the most important cash generating crops for farmers (EHDA 2011).

Ethiopia's potentials to cultivate vegetable crops by smallholders and large commercial growers are enormous. The country has high potential benefit from onion production and the demand for onion bulbs seed and flower is increasing from time to time (Lemma and Shimelis 2003). The total production of onion in Ethiopia in 2012/2013 growing season was 219,919 tons with an average yield of 10.06 tons /ha which is too low compared to the world average of 19.31 tons/ha (FAOSTAT 2013).

There are a number of production problems that limit onion production in the Tigray region in general. The low yield of onion is because of non-optimal agronomic practices, unavailability and high cost of seed, the prevalence of diseases and insect pests, lack of improved varieties and lack of improved production technologies (Lemma and Shimelis 2003). Therefore, the objective of the study was to evaluate the performance and adaptability of the improved onion varieties and to select the high yielding variety/ies from the tested varieties.

Materials and Methods

The experiment was conducted at Tselemti Wereda and at the Shire-Maitsebri (SMARC) experimental Station during 2015-2017 off-seasons with irrigation. Four improved onion varieties (Bombey red, Adama red, Nasik red & Nafis) and Shendi (from Sudan) were evaluated for their yield performance for three years. The field experiment was laid out in Randomized

Complete Block Design (RCBD) with four replications and with the treatments assigned randomly to the experimental plots within blocks.

Plot size was 2 x 3 m (6 m^2). Blocks were spaced 1.5 m while plots within each block were 1 meters apart. Each plot had 5 rows of 3 meters long, rows spaced 40 and 10 cms between plants. Recommended rates of DAP (200kg/ha) and Urea (100kg/ha) were used. All other management practices including plowing, cultivation, watering, nursery and transplanting and weeding were applied uniformly to all plots as per the standard recommendations for the crop. Weeds in the experimental area were manually controlled throughout the cropping season.

Methods of agronomic data collection

All data relating to yield and yield components were collected from the central three rows by excluding plants from either end of the rows. For the purpose of data collection two plants/row or six plants/ plot were selected randomly from each plot and observations on growth, yield and yield components such as: plant height, leaf length, leaf number, neck thickness, bulb length, diameter and yield were recorded.

Plant height was measured from the ground level up to the tip of the longest leaf using ruler. Plant height of six randomly selected plants were measured from the central rows of each plot at physiological maturity of the crop and the average was computed. Days to physiological maturity was recorded on plot basis as the actual number of days from date of transplanting to when about 75% of the leaves fell down and 2/3 leaves had turned yellow. The number of fully developed leaves of six randomly selected plants was counted at the active green leaf stages and the average was computed to obtain number of leaves per plant. Leaf length was recorded as the average length of the longest leaves in six randomly selected plants at maturity. Bulb diameter was measured at right angles to the longitudinal axis at the widest circumference of the bulb on six randomly selected plants in each plot using veneer caliper at harvest. Bulb length was the vertical average length of the matured bulb of six randomly selected plants in each plot which was measured by veneer caliper. The average neck thicknesses of six randomly selected plants in each plot were obtained by measuring the neck of bulbs at the narrowest point at the junction of bulb and leaf sheath using a veneer caliper.

Marketable bulb yield and weight of healthy bulbs were determined after discarding the unmarketable bulb. The nationally accepted marketable bulb weight of of onion was 60 g (Tegbew 2011).

Data analysis

All crop data collected in this study were subjected to two way analysis of variance (ANOVA) following a procedure appropriate to a randomized complete block design (Gomez and Gomez 1984). When the treatment effects were significant, least significance differences (LSD) test was used for separating means.

Results and Discussion

The data in (Table 1 and 2) showed a significant ($p<0.05$) variability between the varieties in most of the traits.

Days to bulb maturity

Days to maturity was significantly ($p< 0.05$) influenced by variety. Bombay Red (124.9 days) and Shendi (127 days) matured significantly earlier than the other varieties while Nasik red matured 16.8 days later than Bombey red (Table 1). The variation in maturity among onion varieties might be due to their genetic differences. Bombay Red was the earliest as it matured 23 days earlier than Adama Red followed by Melkam which matured 18 days earlier than Adama Red (Yemane et al 2014). Bombay Red and Adama Red matured in less than 120 or/and in between 110 to 130 days, respectively (EARO 2004). Similarly, Azoom et al (2014) reported significant differences among eight onion varieties for days to bulb maturity.

Leaf length

Leaf length was significantly (P <0.05) affected by variety. Both Nasik (40.27 cm) and Adama red (39.25 cm) showed the highest mean leaf length (Table 1). Nasik red had significantly longer leaf length than Bombay Red (dominant in the testing area). The difference of varieties in leaf length might be genetic. Yemane et al (2014) also reported that Adama Red had longer leaves than Melkam (37.83cm) and Bombay Red (35.17cm). Similarly workers reported differences in leaf length among cultivars (Mondal et al 1986, Ghafoor et al 2003 and Jilani et al 2010).

Plant height

Plant height was significantly (P <0.05) affected by variety. Nasik red, Nafis and Adama red varieties attained maximum height of 45.9, 45.25 and 42.9 cms, respectively, which was significantly different than Bombay Red and Shendi (Table 1).

The difference in plant height among the onion varieties should be genetic as they were tested in the same environment. Tegbew (2011) indicated the mean plant height of Adama Red (62.25 cm) was significantly higher than Bombay Red (56.04 cm). The result was similar to the finding of Ghafoor et al (2003) and Yemane et al (2014) who indicated the presence of significant differences among onion cultivars in plant height.

Table 1. Days to maturity, plant height, number of leafs and leaf length of onion varieties.

S/N	Variety	DM*	Pht (cm)*	ALN*	ALL(cm)*
1	Nasik red	141.7c	45.90a	10.881a	40.27a
2	Shendi	127.0a	37.16b	8.456 c	33.56c c
3	Bombey red	124.9a	30.23c	8.920bc	28.08 d
4	Nafis	134.2b	45.25a	10.057abc	39.52ab
5	Adama red	140.9c	42.90a	10.599ab	36.69bc
	Mean	133.73	40.29	9.78	35.62
	CV (%)	3.4	12.7	20.2	11.0
	LSD	6.402	7.309	2.816	5.594

*, Means in columns followed by the same letter s do not differ significantly at the 5 % level of significance: DM=Days to maturity; pht=plant height; ALN=Average leaf number; ALL=Average leaf length.

Marketable bulb yield

Variety had significant effect ($p<0.05$) on marketable bulb yield. Nasik red had significantly higher marketable bulb yield (35588 kg ha^{-1}) than Bombay and Adama red, the commonly produced varieties in the area (Table 2). A cultivar may perform differently under diverse agro-climatic conditions and various cultivars of the same species grown at the same environment with different management often yield differently due to the genetic makeup of the cultivars and the interaction effects of genotype and environment (Yemane et al 2013). Gautam et al. (2006) also indicated that fresh onion bulb yield was significantly affected by varieties. In agreement with this finding, Rajcumar (1997), Jilani (2004) and Geremew et al (2010) also reported significant difference within onion varieties for marketable bulb yield.

Table 2. Bulb diameter, length, Neck thickness and Marketable bulb yield of onion varieties.

S/N	Variety	ANT(cm)	ABL(cm)*	ABD(cm)*	MY(Kg/ha)*
1	Nasik red	1.424	5.546a	5.816	35588.0a
2	Shendi	1.207	5.674a	5.992	26119.6b
3	Bombey red	1.323	4.899 b	6.039	30005.1ab
4	Nafis	1.319	5.637a	5.863	26362.6b
5	Adama red	1.322	5.436a	5.586	26099.4b
	Mean	1.319	5.438	5.859	288349.
	CV (%)	27.3	7.6	8.9	27.4
	LSD	Ns	0.5924	ns	112868.4

ns=non-significant at 0.05 probablity level; *, Means in columns followed by the same letter do not differ significantly at the 5 % level of significance: ANT=Average neck thickness; ABL=Average bulb length; ABD=Average bulb diameter; MY=Marketable yield.

Conclusion and Recommendation

Onion is widely recognized and an important vegetable condiment in the form of dry bulb and a cash crop in Ethiopia. It is successfully produced under rain-fed and irrigated conditions in different agro-ecologies of the country by both small holders and commercial growers. However, the productivity of onion is not that high due to many production constraints. The use of lower yielder and non-adaptable varieties is among the many problems. So, identification and introduction of suitable and high yielding onion varieties or hybrids is critically important to improve the yield of onion.

So this study evaluated the agronomic performance of five onion varieties at Shire-Maitsebri Agricultural Research center during 2015-2017 under irrigation. The experiment was laid out in randomized complete block design (RCBD) with four replications. Data were collected for phenology of the crop, growth, yield and yield components and analyzed, accordingly.

On the basis of present results, it can be concluded that the onion varieties studied can be easily differentiated from one another due to their distinctive morphological characters and their performance under Tselemti conditions. Therefore, observing the yield, it can be concluded that Nasik is be the best onion variety than Adama and Bombey red which can improve onion production in Tselemti area and therefore should be promoted for demonstration at farmers field in order to cultivate in similar areas in the region.

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1.5. Effects of Inter and Intra-row Spacing on the Yield and Yield Attributes of Onion *(Allium cepa L.) in* Northwestern Zones of Tigray

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Abstract

Onion is one of the most important and high market value crops cultivated in most parts of the World. It is cultivated both for the fresh market and household consumption in Tigray region of northern Ethiopia. However, onion bulb yield is low due to improper plant spacing. Therefore, this field experiment was conducted to determine the optimum plant spacing for maximum productivity of onion in the 2015 and 2016 under irrigated conditions. Four different inter-row (20, 30, 40 and 50 cms) and 3 intra-row (5, 10 and 15 cms) spacings were used and laid out in randomized complete block design with three replications and Bombey red was the test variety. The results revealed that plant height, bulb diameter, weight, length and marketable bulb yield were significantly influenced by plant spacing. The tallest plants and maximum marketable bulb yield were obtained from the narrower spacing. 20 cm inter row and 5 cm intra-row spacings are therefore recommended for onion growers of the study area.

Keywords: Onion, spacing, yield

Introduction

Onion (*Allium cepa* L.) is an important bulb crop, belonging to the family Alliaceae (Hanelt1990). It is one of the most important and popular bulb crops cultivated commercially in nearly most parts of the world. Onions as food, medicine and religious object were known during the first Egyptian dynasty (3200 BC) (Ray and Yadav 2005). It is important in the daily diets of humans worldwide and Ethiopians as well (MoARD 2006). Onion contributes significant nutritional value to the human diet and are primarily consumed for their distinctive flavor in soups, meat dishes, salads, food dressings and sandwiches, medicinal purposes and is also cooked alone as a vegetable.

In Ethiopia, it has an economically important place among other vegetable crops due to ease of production and high productivity per unit area. Due to the increase in small-scale irrigation schemes, the area under onion production is increasing from time to time. According to CSA (2015), about 10 t ha^{-1} yields were obtained during the years 2013-2015. Land covered by onion in the country increased to 33, 063.37 ha and 327,475.25 tons were obtained in 2016/2017 production year alone CSA (2017)

Despite an increase in importance in the human diet and its increasing area coverage, the productivity of onion in Ethiopia (10.1 t ha^{-1}) is much lower than other African countries (CSA 2015). One of the major problems associated with low productivity is inappropriate agronomic practices exercised by farmers. Though Yemane et al (2016) reported limited use of improved seeds and fertilizers by small scale farmers as reasons for low productivity, Saud et al (2013) reported that quality and yield of a particular onion variety is greatly affected by planting density.

Appropriate agronomic practices are therefore crucial to increase the productivity of the crop. However, in Ethiopia, within row and between row spacings of 10 and 20 cms, respectively were used during transplanting of onion seedlings to permanent field and these were recommended 20 years ago. But, plant spacing in the production of onion should depend on type of variety (plant architecture, growth habit etc.), agro-ecology, production system etc. It might therefore be very difficult to give general recommendation on plant spacing for onion to be applied uniformly across agro- ecologies of the country (UAAIE 2001).

Onion growers in the study area produce onion both for home consumption and local market. Farmers produce onion with irrigation in the dry season though, productivity of the crop was low due to poor agronomic practices and no use of improved technologies. Moreover, lack of improved varieties and seed, undetermined nitrogen rate for the area and plant spacing are the outstanding problems of the study area. Therefore, the study was designed to determine the optimum population density for better growth and yield of Bombey red onion variety under the study area conditions.

Materials and Methods

The experiment was conducted during 2015-2017 under irrigation condition at Tselemti and Medebay-zana districts in North Western Zone of Tigray. The experiment was laid out in 4x3 factorial arrangements in a Randomized Complete Block Design (RCBD) with three replications. Two factors which consist of 4 different inter-row spacing (20, 30, 40 & 50 cm) and 3 different intra-row spacing's (5, 10, and 15 cms). Each plot contains 8 rows and different number of plants per row which includes 56, 28 and 19 plants. Bombey red was used as planting material. Seedlings were raised on nursery for about 40 days and seedlings were transplanted and planted at the prescribed plant spacing. All management practices for the crop were applied uniformly as per the recommendation during nursery and field conditions.

Method of data collection

All data relating to yield and yield components were collected from the central three rows by excluding plants from either end of the rows. For the purpose of crop data collection one (1) plants/row or 6 plants/plot were selected randomly from each plot and data on growth, yield and yield components of the crop (plant height, leaf length, leaf number, neck thickness, bulb length, diameter & yield) were recorded.

Plant height (cm) was measured from the ground level up to the tip of the longest leaf using ruler. Plant heights of six randomly selected plants were measured in the central rows of each plot at physiological maturity and the average was computed. Days to physiological maturity was recorded on plot basis as the actual number of days from date of transplanting to when about 75% of the leaves fell down and 2/3 leaves had turned yellow. The numbers of fully developed leaves of six randomly selected plants were counted at the active green leaf stages and the average was computed to obtain number of leaves per plant. Leaf length (cm) was recorded as the average length of the longest leaves in six randomly selected plants at maturity. Bulb diameter (cm) was measured at right angles to the longitudinal axis at the widest circumference of the bulb of six randomly selected plants in each plot using veneer caliper (Saud et al

2013) at harvest. Bulb length (cm) was the vertical average length of the matured bulb of six randomly selected plants in each plot and was measured by Veneer Caliper. The average neck thicknesses of six randomly selected plants in each plot were obtained by measuring the neck of bulbs at the narrowest point at the junction of bulb and leaf sheath using a Veneer Caliper. Marketable bulb yield was determined after discarding the unmarketable bulb and taking the weight of healthy bulbs. Marketable bulbs were those with nationally accepted marketable bulb weight of 60 g according to Tegbew (2011).

Method of data analysis

All data collected in this study were subjected to two-way analysis of variance following a procedure appropriate to factorial randomized complete block design (Gomez and Gomez 1984).When the treatment effects were significant, Duncan's multiple range test was used for mean separation.

Results and Discussion

Analysis of variance exhibited significant differences due to the main effects of inter and intra-row spacings on the growth of onion (Table 1 and Table 2).

Plant height

The analysis of variance showed that plant height was significantly ($P < 0.05$) affected by inter, intra-row spacing and their interactions (Table 1). Plants spaced at 30 cm were significantly taller (43.49 cm) than onion plants grown in other spacing except 40 cm inter-row spacing. The lowest plant height was found in 20 cm inter row (41.53cm) and 5 cm intra-row (41.43 cm) spacing, respectively (Table 1). Height of plant can be considered as one of the indices of plant vigor and it depends upon growth habit of the plant. The result showed that the plants in wider spacing attained the higher height than the closer spacing. The increased plant height at wider inter and intra-row spacing might be due to the change in growth of the onion plants with relatively less competition for growth factors such as mineral nutrients, solar radiation (sun light) and soil moisture. The finding of Khan et al (2003) confirmed that widest plant spacing of 10 cm produced significantly the highest plant height. This value was decreased as plant spacing reduced and ultimately significantly lowest value of this growth parameter was recorded in the closest intra-row spacing of 7.5 cm. Aliyu et al (2008), Jilani et al (2010) and Sikder et al (2010) also reported the closer inter and intra-row spacing resulted shorter plants than wider plant spacing. Similarly, Tesfalegn (2015) reported that plant height of onion plants was significantly affected by inter and intra spacing of cultivars.

Table 1. Main effects of inter- and intra-row spacing on Bulb setting, Bulb Maturity and plant height

Treatments	Days to Bulb Setting*	Days to Bulb Maturity	Plant height (cm)*
Inter row spacing (cm)			
20	68.06b	122.5	41.53b
30	65.19a	122.7	43.49a
40	65.00	123.0	43.36a
50	63.85a	122.6	42.47ab
LSD	2.200*	ns	1.527*
Intra-row spacing (cm)			
5	66.25b	123.60b	41.43b
10	65.92b	123.0b	43.05a
15	64.40a	121.50a	43.86
LSD	1.201*	1.258*	1.302*
CV (%)	6.5	3.1	9.3

ns = non-significant, * means in columns followed by same letter are not significantly different at $\alpha=0.05$.

Bulb diameter

The analysis of variance result showed that both inter and intra-row spacing had a significant ($p < 0.05$) influence on bulb diameter (Table 2). The bulb diameter increased with increase in inter and intra-row spacing. The highest bulb diameter (6.166 cm) and (5.82cm) was obtained at an inter-row spacing of 50 cm and intra-row spacing of 15 cm and that was significantly higher from 20 cm inter row and 5 cm intra row spacing. Small bulb diameter was observed in plants spaced narrowly.

As inter and intra-row spacing increased, bulb diameter also increased (Table 2). The probable reasons for decreased bulb size as inter and intra-row spacing decrease is due to reduced number of leaves per plant which negatively affects the amount of assimilates. Other possible reason could be more severe competition for growth factors between neighboring plants. The trend of decreasing bulb diameter as inter and intra-row spacing decreased was in agreement with Geremew et al (2010) where they recorded highest bulb diameter at intra-row spacing of 10 cm compared to intra-row spacing of 8, 6 and 4 cm for Adama Red variety. Tendaj (2005) recorded larger bulb diameter of 14 to 47% as inter and intra-row spacing increased from 5 to 20 cm in shallot. The present finding was in agreement with many other authors who reported tlarger bulbs of onion obtained in wider spacing (Kantona et al 2003; Akoun 2005 and Hydar et al 2007)

Bulb length

Bulb length too was significantly ($p < 0.05$) affected by inter and intra-row spacing (Table 2). Significantly longest bulb length was recorded in plants spaced at 50 cm inter-row (5.12 cm) and 15 cm intra-row spacing (4.958), while the smallest bulb length of 4.566 and 4.74 cm was obtained from plants spaced at 20 cm and 5 cm inter and intra row spacing, respectively (Table 4). The general trend was that as inter and intra-row spacing decreased so did the onion bulb length. This might be due to the competition of plants for nutrients, light and moisture at narrow spacing i.e. the narrow spacing did not allow the bulbs to have more assimilates available for storage and thus resulted in smaller bulb length. This finding is in agreement with Yemane et al (2013) who reported highest bulb length at wider spacing compared to narrow spacing. Similar results were reported by Khan et al (2003), Hydar et al (2007) and Jilani et al (2010) too.

Bulb neck thickness

The analysis of variance (Table 2) revealed that both inter and intra-row spacing had significantly ($p< 0.05$) affected bulb neck thickness. Significantly thicker bulb neck was observed in plants spaced in 50 cm inter row and 15 cm intra row spacing than on the other spacing's. On the other hand, neck thickness observed at 20 cm inter-row spacing was statistically at par with 30 and 40 cm inter-row spacing. The general trend observed was that as the inter- and intra-row spacings increased neck thickness also increased (Table 2). The decrease in neck diameter in response to a decrease in inter and intra-row spacing could be attributed to the availability of small amount of photosynthesis due to the increasing competition among plants for growth factors. Thick neck in onion is caused by the active onion growth that the neck did not become dormant and resulted to undifferentiated scales with high thickness at wider inter and intra-row spacing (Currah and Proctor 1990). This indicated that thick neck in onion causes delay in bulbing and has a negative impact on bulb yield (Yemane et al 2013). Gautam et al (2006) observed that bulbs with thin necks store longer than bulbs with thick necks. Thick bulb necks take longer to dry after harvesting and provide a high risk for infection of post-harvest storage diseases such as bacterial soft rot (Bosekeng 2012). Jilani (2004) also found bulbs of thick neck in plots of lowest planting density (20 plants m^2) while the plots of highest density (40 plants m^2) produced bulbs of thin neck diameter. The present study is in agreement with the report of Sikder et al (2010) that, the closest spacing significantly produced lower bulb neck thickness. This report was also similar with the reports of Dawar et al (2005) and Khalid (2009) that higher bulb neck thickness was observed in plants spaced at wider plant spacing, while the lowest in plants spaced at closer intra-row spacing.

Marketable bulb yield

Inter and intra-row spacing had significant effect ($p< 0.05$) on marketable bulb yield (Table 2). The highest marketable bulb yield of 30552 kg/ha was obtained from the wider inter row spacing and similarly the highest marketable bulb yield of 28900 kg/ha was obtained from 5 cm intra-row spacing. As inter and intra-row spacing decreased, marketable bulb yield was increased. Similarly, Khalafalla (2001) reported significantly higher marketable bulb yield with closer spacing in potato. Geremew et al (2010) reported intra-row spacing have effect on marketable yield while Yemane et al (2013) found out that decreased marketable bulb yield with increased intra-row spacing. Khan et al (2003) also reported higher marketable bulb yield as the plant spacing decreased.

Conclusion and Recommendation

Study was conducted in North western zone of Tigray to determine optimum inter and intra-rows pacing for maximum yield of onion. Factorial combination of four inter- row and three intra-row spacing were laid out in a randomized complete block design (RCBD) with three replications. Different phonological and yield related traits were examined. Significant variations due to spacing were recorded in plant height, bulb diameter, length, neck thickness and marketable bulb yield. The main effects of inter-row spacing caused significant variation on plant height, bulb diameter, bulb length, bulb neck thickness and marketable bulb yield and wider inter-row spacing's brought about higher values for those parameters. The highest marketable bulb yield per hectare was obtained from combination of 5 cm intra-row spacing and

Table 2. Main effects of inter- and intra-row spacing on bulb diameter, length, neck thickness and marketable bulb yield

Treatments	Bulb diameter*	Bulb Length*	Bulb neck thickness*	Marketable bulb yield*
Inter row spacing (cm)				
20	5.164c	4.566c	1.148b	30552a
30	6.166a	4.813b	1.212b	26598b
40	5.756b	4.951b	1.233b	23468c
50	5.619b	5.124a	1.427a	20960c
LSD	0.4	0.1585	0.1515	2826.4
Intra-row spacing (cm)				
5	5.439b	4.749b	1.223b	28900a
10	5.762a	4.884ab	1.221a	25302b
15	5.82a	4.958a	1.321a	21982 c
LSD	0.2618	0.1532	0.0960	2546.5
CV (%)	14.0	9.6	23.3	30.5

*, means in columns followed by the same letter are not significantly different at α=0.05.

20 cm inter row spacing. On the other hand, the lowest total and marketable bulb yield per hectare were recorded from the combination of 15 cm intra-row and 50 cm inter-row spacing. In general, the closest inter- and intra-row spacing gave higher marketable and total bulb yield compared to the wider spacing. Thus, growers in the study area can benefit from the closer spacing and is therefore recommended.

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2. Natural Resources Management Technologies

2.1. Effect of NPSKZnB Blended Fertilizer on Yield and Yield Components of Onion (*Allium cepa*) in North Western Tigray, Ethiopia

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Abstract

The previous fertilizer recommendation based on Urea and DAP is considered as unbalanced and formulated based on very general and single recommendation for all soil and crop types. Based on this premise, soil fertility Atlas of Tigray with recommendations for blended fertilizer use was prepared and published. However, validation of the blended fertilizer recommendation is needed. This study was therefore initiated to evaluate and determine the effect of blended fertilizer on yield and economic return of onion. Field experiment was carried out during the years 2016-2017 under irrigation at Tahtay Koraro and Laelay Adyabo districts of the Tigray regional state, Northern Ethiopia. The experiment was conducted in a randomized complete block design with three replications. Seven treatments of NPKSZnB levels (25, 50, 100, 150, 200, 250 and 300 kg ha^{-1}) were tested. Nitrogen from Urea was top-dressed at a rate of 69 kg N $ha^{-1}$for each plot. Surface soil samples were collected before planting and analyzed for selected soil properties. Highest mean onion yields of 10329 and 19196 kg ha^{-1} were obtained in response to application of 200 and 250 kg ha^{-1} blended fertilizer at Tahtay Koraro and Laelay Adyabo districts, respectively. However, NPKSZnB rates of 100 and 50 kg ha^{-1} under irrigation condition were found to be economically profitable for onion production at Tahtay Koraro and Laelay Adyabo districts, respectively. Therefore, producers at both districts are advised to use the blended NPKSZnB fertilizer at these rates for economical production of onion.

Keywords: Blended fertilizer, Onion, yield

Introduction

Agriculture has continued to keep its importance in Ethiopia's economic growth contributing 42%, 80% and 70% in subsidizing GDP, employment and export earnings, respectively (African Economic Outlook 2015). Almost 85% of the rural population in Ethiopia depends on agriculture. Agriculture contributes to improvement of economic growth; reduction of poverty and food insecurity in Ethiopia. The majority of Ethiopian farmers are small-scale producers. Estimates shows that about 94% of Ethiopian farmers rely on less than 5 hectares of land, of which 55% cultivate less than 2 hectares (Lulit et al 2016). Crop productivity still remains very low relative to its potential yields, only averaging 2.21 t ha^{-1} between 2010 and 2014 (World Bank 2014). Moreover, only 5% of the country's agricultural land is irrigated, largely leaving agriculture to the fate of unreliable and poorly distributed rains. According to CSA (2014), low productivity could be attributed to many factors including land degradation, small farm size, recurrent drought and poor farm technology.

Despite the use of fertilizers in irrigated agriculture nation wise, its economic return is low. This is because the current fertilizer recommendation in Ethiopia is based on very general or more often a single recommendation. In the early 70's with an initial understanding that nitrogen and phosphorus are the major limiting nutrients, nationwide on-farm demonstrations trials were conducted and as a result a blanket rate of 100 kg ha^{-1} DAP or 50 kg urea ha^{-1}+ 100 kg DAP ha^{-1} were recommended irrespective of crop and soil types (NFIU 1993). This blanket recommendation often fails to consider the differences in resource endowment (soil and crop types, climate) or make allowances for dramatic changes in input/output price ratio, thereby discouraging farmers from fertilizer application.

Moreover, the blanket recommendation has favored the emergence of multi-nutrient deficiencies in Ethiopian soils (Abyie et al 2003, Beyene 1984; Wassie et al 2011). This in part might have led to decline in soil productivity due to sub-optimal fertilizer use in one hand and unbalanced fertilizer use on the other. Absence of one or more nutrients despite continued use of N and P fertilizer can hold back crop productivity. This could explain, in part, the modest crop yield improvements observed over the last few decades in contrast to significant increases in fertilizer use and investment made in the country. Today, in addition to N and P; there exists a widespread deficiency of K, S, B and Zn in Ethiopian soils, while some soils particularly in Tigray are also deficient in Fe (EtioSIS 2014). Therefore, future gains in food grain production will be more difficult and expensive bearing in mind the growing problem of multi-nutrient deficiencies.

Integrated use of suitable fertilizer types and cropping system is the key for sustainable crop production as proper combination of fertilizers and cropping system can increase crop yield by 50% (Zia et al 1991). Better and matching fertilizer recommendations to local climate, soil, and management practices helps ensure that production can be intensified in a cost-effective and sustainable way and, thereby, enhance regional as well as national food security. Optimum use of fertilizers to overcome the constraints of low nutrient recovery needs to replace such general and over-simplistic fertilizer recommendation with those that are rationally differentiated according to climate, soils and crop types, plant nutrient requirements and socio-economic circumstances of farmers.

Different area specific blended fertilizers which contain those deficient nutrients were formulated by EthioSIS (2014). However, it should be noted that, other than indicating the soil fertility status and recommending the most appropriate blended fertilizers for each district, the soil fertility Atlas doesn't contain information about recommended fertilizer application rates. Therefore, the objectives of this study were to promote sustainable intensification of the major vegetable production systems through development of crop and soil specific balanced fertilizer recommendations and determine the optimum rates that would result in the highest onion production with highest economical return.

Materials and Methods

Study area

Field experiments were conducted for two consecutive seasons in the years 2016- 2017 under irrigated conditions on two selected farmer’s fields at Tahtay Koraro (Mai-dmu irrigation scheme) and Laelay Adyabo (Meskebet irrigation scheme) districts of North Western Tigray, northern Ethiopia. These areas predominantly lie under semi-arid tropical belt of Ethiopia with a hot to warm agro-climatic zone, with a mono-modal and erratic rainfall pattern. Mai-dmu and Meskebet irrigation schemes are found at around 30 km away to the west of Shire Indasilassie town ($14^{0}6$ N and $38^{0}17$ E) and 15 km away southeast of Adi-daero town, respectively. Adi-daero is around 30 km North Western of Shire Indasilassie town.

Experimental design, treatments and procedures

The study sites were selected based on the blended fertilizer (NPKSZnB) recommendationsof Ethiosis (2014). Seven treatments (25, 50, 100, 150, 200, 250, 300 kg NPKSZnB ha^{-1}) were formulated. The treatments were laid out in Randomized Complete Block Design (RCBD) with three replications. Plot size was 3 m by 3 m for onion planted in rows, replicated 3 times on site and across two farmers' fields of each districts. Additional N was applied as basal to each plot at a rate of 69 kg N ha^{-1} because it was low in the study sites and the content in the blended fertilizers might not satisfy the need of the crop. Blended fertilizers and half of N were applied at planting while the rest N was top-dressed 45 days after planting. The test crop (Var. Bombay Red) was planted in rows with 40x20x10 cms spacing between ridges, double rows and plants, respectively. All crop management practices were applied as per the recommendation for onion.

Soil data collection and analysis

Before planting one representative composite soil sample was taken at 0-30 cm depth from each study sites and farmer's fields using an auger. The collected samples were properly labeled, packed and transported to Shire Soil Research Center. Particle size distribution was determined using the Bouyoucos hydrometer method (Bouyoucos 1962). The pH of the soil was measured in the supernatant suspension of 1: 2.5 soils to water ratio using a pH meter (Rhoades 1982). Electrical conductivity (EC) of 1:25 soil to water suspension was measured according to the method described by Jakson (1967). Organic carbon was determined by the Walkely and Black

(1934) method while total N using the Kjeldahl method as described by Bremner and Mulvaney (1982). Available P was determined following Olsen method (Olsen et al 1954).

Crop data collection

Agronomic data like marketable yield, single bulb weight, bulb diameter, bulb length, leaf length, leaf number per plant, plant height and days to 90% maturity and planting date were collected.

Data analysis

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

Partial budget analysis

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

Results and Discussion

Experimental soil characteristics before planting

Some of the selected soil physical and chemical properties of the experimental sites are indicated in table1. The soils from Tahtay Koraro was sandy loam in its texture while that of Laelay

Adyabo was clayey. Soil pH from Tahtay Koraro was moderately acidic while from Laelay Adyabo was neutral according to the rating of Tekalign (1991). On both sites soil were non-saline in their nature. The cation exchange capacity (CEC) of the soils of Tahtay Koraro was low while that of Laelay Adyabo was high with low exchangeable K in both the sites (Landon 1991). The soil organic carbon and total N were low in both sites according to the rating of Tekalign (1991). Available P was also low in the soil of Tahtay Koraro while soil from Laelay Adyabo site had medium in its available P content (Olsen 1954).

Table 1. Surface (0-30 cm deep) soil properties of the experimental soils

Soil properties	Tahtay Koraro	Laelay Adyabo
Clay (%)	7	56
Silt (%)	34	25
Sand (%)	59	19
Textural Class	Sandy Loam	Clayey
Bulk density (g cm^{-3})	1.49	1.33
pH	5.3	7.05
EC (dS m^{-1})	0.22	0.42
CEC (cmol(+) kg^{-})	12.7	49
OC (%)	0.50	0.71
Total N (%)	0.052	0.075
Available P (mg kg^{-1})	4.1	6.4
Exc.K (cmol(+) kg^{-1})	0.23	0.31

2.2. Effects of NPKSZnB fertilizer on phenology, growth and yield of onion

Days to physiological maturity and plant height of onion under irrigation condition was significantly ($p \leq 0.05$) affected by different NPKSZnB rates (Table 2) both at Tahtay Koraro and Laelay Adyabo districts. The physiological maturity of onion was delayed in plots that received 100 and 200 kg NPKSZnB ha^{-1} rates at Tahtay Koraro and Laelay Adyabo districts, respectively (Table 2). Though it is in parity with the 200 and 250 kg NPKSZnB ha^{-1} maturity was hastened on plots that treated with 25 kg NPKSZnB ha^{-1} at Tahtay Koraro, whereas days the onion took to mature was shorter (mean days of 135) in plots that received a rate of 250 kg NPKSZnB ha^{-1} at Laelay Adyabo district. The highest and lowest onion plant heights at Tahtay Koraro district were 41.70 and 37.77 cm, while at Laelay Adyabo were 37.4 and 31.03 cm, respectively (Table 2). Longer plants were recorded from the blended fertilizer rate of 150 and 300 kg ha^{-1} NPKSZnB, whereas the shortest plants were recorded on plots that received 50 and 100 kg ha^{-1}NPKSZnB for Tahtay Koraro and Laelay Adyabo districts, respectively.

Table 2. Days to 90% physiological maturity and plant height of onion as influenced by blended NPKSZnB fertilizer rate under irrigation condition.

Fertilizer rate (kg ha^{-1})	Two years result combined for each district			
	Tahtay Koraro		Laelay Adyabo	
	DM (days)	PH (cm)	DM (days)	PH (cm)
25 NPKSZnB (kg ha^{-1})	118. 83a	38.60ab	136.83cd	34.30ab
50 NPKSZnB (kg ha^{-1})	119. 67bc	37.77b	136.50bcd	35.30ab
100 NPKSZnB (kg ha^{-1})	121.33c	40.33ab	135.33ab	31.03b
150 NPKSZnB (kg ha^{-1})	120.83bc	41.70a	136.33abcd	37.20a
200 NPKSZnB (kg ha^{-1})	119.83ab	39.67ab	137.50d	34.57ab
250 NPKSZnB (kg ha^{-1})	120.50abc	38.13ab	135.00a	37.10a
300 NPKSZnB (kg ha^{-1})	119.83bc	40.47ab	135.83abc	37.40a
Mean	120.26	39.52	136.19	35.27
LSD (0.05)	1.00	3.89	1.47	6.05
CV (%)	0.71	8.41	0.92	14.63

DM= Days to 90% Maturity and PH= Plant height

Leaf numbers per plant of onion was significantly ($p \leq 0.05$) affected by the different rates of NPKSZnB at Laelay Adyabo only (Table 3). The highest number of leaves per plant (33.53) was recorded from plots that received 300 kg ha^{-1} blended NPKSZnB fertilizer rate, whereas the lowest number of leafs per plant (27.47) were recorded from 100 $kgha^{-1}$ NPKSZnB at Laelay

Adyabo. Onion leaf length was also influenced siginficanlty by fertilizer rates at both sites. The longest leaveas at Tahtay Koraro (34.00 cm) and Laelay Adyabo (38.97 cm) were recorded from NPKSZnB rates of 150 and 250 kg ha^{-1}, whereas the shortest leaves (31.00 cm) and (28.27 cm) were recorded for plots that received 50 and 25 kg ha^{-1} NPKSZn fertilizer, respectively.

Bulb length and diameter of onion were significantly ($P \leq 0.05$) affected by the different rates of NPKSZnB at both districts (Table 4). The longest onion bulbs for Tahtay Koraro and Laelay Adyabo (4.76 and 5.10 cm) were recorded in response to NPKSZnB applied at the rates of 200 and 250 kg ha^{-1}, whereas the shortest bulbs (4.23and 4.60 cm) were from plots that received 25 kg ha^{-1}NPKSZnB fertilizer, respectively. The highest bulb diameter (8.45 cm at Tahtay Koraro and 9.33 at Laelay Adyabo) were recorded from blended rates of 300 and 150 kg NPKSZnB ha^{-1}, correspondingly. Similarly, the least bulb diameters (8.31 cm at Tahtay Koraro and 8.33 cm Laelay adyabo) were recorded from plots that received 100 and 25 kg NPKSZnB ha^{-1} rates, respectively.

Table 3. Number of leaves per plant and leaf length of onion as influenced by blended NPKSZnB fertilizer rate under irrigation condition

Fertilizer rate (kg ha^{-1})	Two years result combined for each district			
	Tahtay Koraro		Laelay Adyabo	
	LN (numbers)	LL (cm)	LN (numbers)	LL (cm)
25 NPKSZnB (kg $ha\text{-}^{1}$)	21.87	31.83ab	28.50a	28.27d
50 NPKSZnB (kg $ha\text{-}^{1}$)	22.57	31.00b	31.40ab	33.80c
100 NPKSZnB (kg $ha\text{-}^{1}$)	22.90	31.83ab	27.47b	35.70bc
150 NPKSZnB (kg $ha\text{-}^{1}$)	23.13	34.00a	31.53ab	36.67ab
200 NPKSZnB (kg $ha\text{-}^{1}$)	22.37	31.17b	27.77b	33.90c
250 NPKSZnB (kg $ha\text{-}^{1}$)	21.83	31.23b	31.60ab	38.97a
300 NPKSZnB (kg $ha\text{-}^{1}$)	22.40	32.80ab	33.53a	38.53a
Mean	22.44	31.98	30.26	35.12b
LSD	NS	2.67	4.45	2.51
CV (%)	12.42	7.11	12.55	30.12

LN= Leaf number per plant and LL= Leaf length

Table 4. Bulb length and bulb diameter of onion as influenced by blended NPKSZnB rate under irrigation condition

Fertilizer rate (kg ha^{-1})	Two years result combined for each district			
	Tahtay Koraro		Laelay Adyabo	
	BL (cm)	BD (cm)	BL (cm)	BD (cm)
25 NPKSZnB (kg ha-[1])	4.23	8.59	4.60	8.33b
50 NPKSZnB (kg ha-[1])	4.37	8.34	4.63	8.43b
100 NPKSZnB (kg ha-[1])	4.48	8.31	4.87	8.07bc
150 NPKSZnB (kg ha-[1])	4.47	8.33	4.87	9.33a
200 NPKSZnB (kg ha-[1])	4.76	8.79	4.78	7.53c
250 NPKSZnB (kg ha-[1])	4.32	8.45	5.10	7.97bc
300 NPKSZnB (kg ha-[1])	4.40	8.87	5.03a	7.57c
Mean	4.43	8.52	4.84	8.18
LSD	0.45	0.50	0.46	0.65
CV (%)	8.61	12.39	17.25	20.90

BL= Bulb Length, BD= Bulb Diameter

Single bulb weight and marketable yield of onion were significantly ($p \leq 0.05$) influenced by different NPKSZnB rates at both districts (Table 5). Highest single bulb weight of 290 and 320 g at Tahtay Koraro and Laelay Kdyabo, respectively were obtained in response to 300 kg NPKSZnB ha^{-1} application. Likewise, the least single bulb weight of 211g and 197 g were recorded from plots that received 50 and 25 kg NPKSZnB ha^{-1} for the two study areas, respectively. Single bulb weight of onion increased with an increase in the rate of blended NPKSZnB fertilizer at both study areas. Highest marketable yields of 10329 and 19196 kg ha^{-1} at Tahtay Koraro and Laelay Adyabo, respectively, were recorded in response to the application of 200 and 250 kg ha^{-1} blended fertilizer. Least marketable yields of 6841 and 13190 kg ha^{-1} at Tahtay Koraro and Laelay Adyabo, correspondingly, were obtained in response to the lowest rate of blended fertilizer (25kg ha^{-1}) in both districts.

Table 5. Single bulb weight and marketable yield of onion as influenced by blended NPKSZnB fertilizer rates under irrigation condition

Fertilizer rate (kg ha^{-1})	Two years result combined for each district			
	Tahtay Koraro		Laelay Adyabo	
	SBWt (g)	MY (kg)	SBWt (g)	MY (kg)
25 NPKSZnB (kg ha-[1])	218bc	6841c	197b	13190b
50 NPKSZnB (kg ha-[1])	211c	7578bc	240b	15736ab
100 NPKSZnB (kg ha-[1])	216c	9535ab	273ab	17647a
150 NPKSZnB (kg ha-[1])	230bc	9380ab	270b	18731a
200 NPKSZnB (kg ha-[1])	264ab	10329a	250b	15806ab
250 NPKSZnB (kg ha-[1])	237bc	9128abc	300ab	19196a
300 NPKSZnB (kg ha-[1])	290a	10233a	320a	16401ab
Mean	238	9003.32	264	16672.48
LSD	47	2339.50	55	4235.90
CV (%)	16.77	22.17	16.73	21.67

SBWt= Single bulb weight and MY= Marketable yield

Partial budget analysis

The maximum onion yields were recorded from plots that received 200 and 250 kg NPKSZnB ha^{-1} at Tahtay Koraro and Laelay Adiyabo districts, respectively (Tables 5 & 6). However, there was no economic return beyond the rates of 100 and 50 kg NPKSZnB ha^{-1}atTahtay Koraro and Laelay Adyabo districts, respectively (Table 6). Thus, application of 100 and 50 kg ha^{-1}NPKSZnB fertilizer for onion could be economical to improve productivity of onion.

Table 6. Partial budget analysis of blended NPKSZnB fertilizer for onion at Tahtay Koraro and Laelay Adyabo ditricts

Fertilizer rate (kg K/ha)	FC (Birr)	TLC [Birr]	TVC [Birr]	MY (kg/ha)	AjY (kg/ha)	TR [Birr]	NR [Birr]	MRR (ratio)	MRR (%)
Tahtay Koraro									
25 NPKSZnB (kg ha-[1])	445.41	30	475.41	6841	6156.9	123138	122662.6	0	0
50 NPKSZnB (kg ha-[1])	890.82	60	950.82	7578	6820.2	136404	135453.2	26.90	2690.43
100 NPKSZnB (kg ha-[1])	1781.64	120	1901.64	9535	8581.5	171630	169728.4	36.05	3604.80
150 NPKSZnB (kg ha-[1])	2672.46	150	2822.46	9380	8442	168840	166017.5	D	D
200 NPKSZnB (kg ha-[1])	3563.28	210	3773.28	10329	9296.1	185922	182148.7	D	D
250 NPKSZnB (kg ha-[1])	4454.1	270	4724.1	9128	8215.2	164304	159579.9	D	D
300 NPKSZnB (kg ha-[1])	5344.92	330	5674.92	10233	9209.7	184194	178519.1	D	D
Laelay Adyabo									
25 NPKSZnB (kg ha-[1])	445.41	30	475.41	13190	11871	237420	236944.6	0	0
50 NPKSZnB (kg ha-[1])	890.82	60	950.82	15736	14162.4	283248	282297.2	95.40	9539.68
100 NPKSZnB (kg ha-[1])	1781.64	120	1901.64	17647	15882.3	317646	315744.4	35.18	3517.72
150 NPKSZnB (kg ha-[1])	2672.46	150	2822.46	18731	16857.9	337158	334335.5	20.19	2018.98
200 NPKSZnB (kg ha-[1])	3563.28	210	3773.28	15806	14225.4	284508	280734.7	D	D
250 NPKSZnB (kg ha-[1])	4454.1	270	4724.1	19196	17276.4	345528	340803.9	63.18	6317.62
300 NPKSZnB (kg ha-[1])	5344.92	330	5674.92	16401	14760.9	295218	289543.1	D	D

FC= Fertilizer cost, TLC= transport and labor cost, TVC= Total variable cost, MY= marketable yield, AjY= Adjusted yield, TR= Total Revenue, NR= Net revenue and MRR= marginal rate of return.

Note:-TVC = FC + TLC

AjY = MY- (MY*10%)

NR = TR-TVC

MRR= MRR is the ratio of $(NR_n-NR_{n-1})/(TVC_n-TVC_{n-1})$ *where n is number of treatments

Conclusion and Recommendation

Application of different rates of blended NPKSZnB fertilizer significantly influenced most of onion yield and yield components in both study areas. Marketable yield showed increasing trend with an increase in rate of blended fertilizer. Highest mean marketable yield of onion was obtained in response to the application of the 200 and 250 kg ha^{-1} blended fertilizer rates at Tahtay Koraro and Laelay Adyabo districts, respectively. However, there was no economic return beyond the rates of 100 and 50 kg NPKSZnB ha^{-1} at Tahtay Koraro and Laelay Aadyabo districts, respectively (Table 6). Thus, application of 100 and 50 kg ha^{-1}NPKSZnB fertilizer with 69 kg N ha^{-1} could be economical to improve productivity of onion. Further popularization and scale is needed. Researchers can also benchmark the rates for further study in different soil and crop conditions. Besides further study on blended fertilizers without K is needed because K in the blend might not be enough for the crop demand or may be affected by fixation.

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2.3. Effects of Mineral Nitrogen and Phosphorus Fertilizer Rates on the Growth, Yield and Yield components of Onion *(Allium cepa L.)* in North Western Zone of Tigray

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Abstract

Onion (*Allium cepa* L.) is one of the most important high market value bulb crops cultivated commercially in most parts of the world. It is the most cultivated high market value vegetable crop in Tigray, Northern Ethiopia. However, bulb yield of onion is limited due to low fertility of soil and inappropriate fertilizer rate. Therefore, field experiment was conducted in 2016 and 2017 under irrigation conditions to determine the optimum rates of nitrogen and phosphorus fertilizers to maximize onion productivity. Six different levels of nitrogen (0, 23, 46, 69, 92 and 115 kg N ha^{-1}) were combined with six different levels of phosphorus (0, 46, 69, 92,115 and 138 kg P_2O_5 ha^{-1}) and were laid out in randomized complete block design replicated three times. 'Bombey Red' was the variety used. The findings showed that the highest marketable bulb yield (23.8 t ha^{-1}) was obtained with 69 kg N ha^{-1} + 92 kg P_2O_5 ha^{-1}.

Keywords: Fertilizers, nitrogen, onion, phosphrous

Introduction

Onion (*Allium cepa L.*) is an important underground vegetable bulb crop of the tropical and subtropical part of the world (Golani et al 2006). It belongs to the genus *Allium* of the family *Alleacea* (Hanelt 1990; Griffiths et al 2002), which originated in southwest Asia and the Eastern Mediterranean regions through Turkmenistan, Tajikistan to Pakistan and India, which are the most important sources of genetic diversity (Brewster 2008). Onion is one of the oldest cultivated vegetables which can be traced back to 5000 years and has been in cultivation for more than 4000 years. Onion as food, medicine and religious object, was known during the first Egyptian dynasty in 3200 B.C (Ray and Yadav 2005). Onion, which is different from the other edible species of *Alliums* for its single bulb, is usually propagated by true botanical seed (Hanelt 1990; Corgan et al 2000).

Onion is considerably important in the daily diets of humans worldwide and as well as in the Ethiopian; mostly used as seasonings or as vegetables in stews (MoARD 2009). It contributes significant nutritional value to the human diet and are primarily consumed for their distinctive flavor widely used in soups, meat dishes, salads, food dressings and sandwiches and medicinal purposes. Onion is the richest sources of flavonoids in the human diet and flavonoid consumption has been associated with a reduced risk of cancer, heart disease and diabetes. Its pungency is due to the presence of a volatile oil (Allyl propyl disulphide). In addition, it is known for antibacterial, antiviral, anti-allergenic and anti-inflammatory potentials. In Ethiopia, onion, spread throughout the country, is cultivated under irrigated and rain-fed conditions in different agro-climatic regions and there is considerable increase of its importance in the daily human diets (Lemma and Herath 1992).

The diverse agro-climatic conditions that prevail in the country provide the opportunity for producing onion bulb, seeds and cut flower for local and export market. The high yield potential, ease of propagation by seed, high domestic demand and export markets for fresh and processed forms is making the crop very important in Ethiopia. There are a number of constraints for its low productivity in Ethiopia though. The low yield of onion in the country is reported to be due to low fertility of soil, inappropriate fertilizer rate, lack of improved varieties and poor management practices (Lemma and Shimelis 2003).

Onions are weaker than most other crop plants in extracting nutrients from the soil, especially the immobile types because of their shallow and unbranched root system; hence they require and often respond well to fertilizers (Brewster 1994). Nitrogen and phosphorus are often referred to as the primary macro-nutrients because of the probability of plants being deficient in these nutrients and because large quantities are taken up from the soil relative to other essential nutrients (Marschner 1995).

So far, in Ethiopia, the recommended fertilizer rate for Onion is 200 kg/ha DAP and 100 kg/ha for Urea (EARO 2004). However, in the North Western zone of Tigray farmers used different rates of N and P fertilizers. So, determining the optimum fertilizer rate in North Western Tigray is very important. Hence a study was conducted to determine the optimum nitrogen (N) and phosphorus (P) fertilizer rates for better onion yield in the North Western Zone of Tigray.

Materials and Methods

Study site, experimental design, treatments and procedures

Field experiments were conducted during 2016-2017 under irrigation in North Western Zone of Tigray at Tselemti and Tahtay Koraro districts and in the experimental Station of Shire-Maitsebri Agricultural Research Center (SMARC. The experiment was laid out in a factorial randomized complete block design (RCBD) with three replications. The experiment consisted of six nitrogen (0, 23, 46, 69, 92 and 115 kg N ha^{-1}) and six phosphorus (0, 46, 69, 92, 115 and 138 kg P_2O_5 ha^{-1}) levels. Each treatment combination was the assigned randomly to the experimental units within a block. There were 36 plots corresponding to the 36 treatment combinations. The unit plot size of the experiment was 2.0 m x 2.0 m (4 m^2). The blocks were separated by a distance of 1.5 m whereas the space between each plot within a block was 1.0 m. There were 5 rows in each plot and the central three rows were used for data collection, considering the two outermost rows as border. The test variety was Bombey red. The seeds of 'Bombey red' variety were raised on nursery for about 40 days. Finally, seedlings were transplnated and planted at the prescribed inter- and intra-row spacings. All management practices for the crop were applied uniformly as per recommendation during nursery and field conditions.

Agronomic data collection

All data were collected from the central three rows by excluding plants from either end of the rows. For the purpose of data collection six (6) plants per plot were selected randomly and observations on plant height, number of leaves, bulb fresh weight, bulb length, buld diameter and marketable yield were recorded periodically. Plant height was measured from the ground level up to the tip of the longest leaf using ruler. Plant height of six randomly selected plants were measured at physiological maturity stage of the crop and the average was computed. The numbers of fully developed leaves of six randomly selected plants were counted at the active green leaf stages and the average was computed to obtain number of leaves per plant. Bulb diameter was measured at right angles to the longitudinal axis at the widest circumference of the bulb of six randomly selected plants in each plot using veneer calliper (Saud et al 2013) at harvest. Bulb length as the vertical average length of the matured bulbs of six randomly selected plants in each plot was measured by veneer calliper. Marketable bulb yield was determined by taking the weight of healthy bulbs, after discarding the unmarketable bulb. The nationally accepted marketable bulb weight of 60 g was considered (Tegbew 2011) and the marketable bulb weight from each plot was converted to t ha^{-1}.

Method of agronomic data analysis

Collected data were subjected to two way analysis of variance (ANOVA) following a procedure appropriate to randomized complete block design (Gomez and Gomez 1984). When there were significant treatment differences, least significance differences (LSD) were used for mean separation at 0.05 level of probability.

Results and Discussion

Plant height

Main effect of nitrogen and phosphorus fertilizer application significantly ($p< 0.05$) influenced plant height of the onion at physiological maturity (Table1). Increasing nitrogen rate from 0 up to

115 kg N ha^{-1} resulted in a linear increase in plant height. However, increasing nitrogen beyond 46 kg N ha^{-1} did not significantly change the height of the onion plants. The tallest plants were obtained at 115 kg N ha^{-1} (Table 1).The increase in plant height due to increased nitrogen rates may be attributed to the role the nutrient plays in enhancing cell division, cell elongation, chlorophyll synthesis and protein synthesis which finally enhances the growth of onion plants (Jilani et al 2004; Aliyu et al 2007; Nasreen et al 2007 and Gustfson 2010). This result confirms the findings of Singh et al (1994) who observed that 80 kg N ha^{-1} resulted in the tallest plants. The result also agrees with the findings of Aliyu et al (2007), Nasreen et al (2007) and Al-Faraiht (2009) who reported increased nitrogen rates to have resulted in increased heights of onion plants. Similar results were also reported by El-Shaikh (2005) and Abdissa et al (2011).

Table 1. Main effect of nitrogen and phosphorus fertilizers on plant height, number of leaves and bulb fresh weight

Treatments	Plant height (cm)	Number of leaves	Bulb fresh weight (g)
Nitrogen (kg ha^{-1})			
0	39.21c	9.970	68.02c
23	40.86b	9.806	76.47b
46	42.31a	10.082	81.04ab
69	42.13a	10.205	81.71ab
92	42.20a	9.872	82.56a
115	42.67a	9.637	81.55ab
LSD	1.193	ns	5.199
Phosphorous (kg P_2O_5 ha^{-1})			
0	39.21c	9.970	68.02
46	40.86b	9.806	76.47
69	42.31a	10.082	81.04
92	42.13a	10.205	81.71
115	42.20a	9.872	82.56
138	42.67a	9.637	81.55
LSD	1.193	ns	Ns
CV (%)	8.8	16.1	20.2

Bulb fresh weight

Fresh bulb weight of onion was significantly affected by the main effect of nitrogen application. However, the main effect of phosphorus did not affect the mean fresh bulb weight of onion (Table 1). When nitrogen rate was increased from 0 to 46 kg Nha^{-1}, there were significant and linear increments in mean fresh bulb weights. When the rate of fertilizer was elevated from 46 kg N ha^{-1} to 115 kg N ha^{-1}, the mean fresh bulb weight didn't change significantly. Thus, the heaviest bulbs were obtained at 92 N kg ha^{-1} (Table 1). Mean fresh bulb weight increase in response to nitrogen application could be attributed to the increase in number of leaves produced, leaf length, and extended physiological maturity in response to the fertilization, all of which may have led to increased assimilate production and allocation to the bulbs (Kokobe et al 2013). Results of the present study are in line with the findings of Shimelis (1997) who also reported that irrigated onion plants benefited from application of 90-120 kg N ha^{-1} compared to unfertilized crops on a sandy loam soil in a semi-arid region of Ethiopia. Similarly, Kokobe et al (2013) found out that the heaviest onion bulbs were recorded in response to the application of 100 kg N ha^{-1}.

Bulb diameter

Nitrogen fertilization significantly increased the mean bulb diameter but application of phosphorus and the interaction of nitrogen and phosphorus didn't significantly influence bulb diameter of onion (Table 2). In response to raising the rate of nitrogen from nil to the 23, 46, and 69 kg N ha^{-1}, bulb diameter increased significantly. However, increasing tnitrogen rate beyond 46 kg N ha^{-1}, did not significantly increase bulb diameter. The significant increase in bulb diameter in response to the increment of N rate may be linked to the increase in dry matter production and its' partitioning to the bulb. Abdissa et al (2011) reported that application of 69 kg ha^{-1} increased the bulb diameter by about 11% as compared to the control. This could be due to the activities of N in different physiological and metabolic processes through increase in dry matter production (Maier et al 1990).

Marketable bulb yields

Nitrogen had significant effects on marketable bulb yields of onion. However phosphorus did not affect the marketable bulb yields of onion (Table 2). Increasing N rate from 0 to 23, 46, 69, 92 and 115 kg N $ha^{-1,}$ increased marketable bulb yield. However, an increase beyond 69 kg N ha^{-1} did not increase marketable bulb yields. Thus, the highest marketable bulb yields were obtained at 69 kg N ha^{-1} (Table 2). The results indicated that applying more than 69 kg N ha^{-1} is supraoptimal for onion bulb yields in the study area. The significant increments in marketable bulb yields in response to nitrogen application may be attributed to enhanced growth and expansion of leaf surface area and vegetative growth as a whole as a result of nitrogen assimilation by the plants, which may have led to increased photosynthesis, and eventually partitioning of markedly higher carbohydrates to the bulbs at maturity. This suggestion is consistent with that of Birhanu et al (2014) who reported that the increase in onion bulb yield with application of nitrogen fertilizer could be due to the fact that nitrogen increases the rate of metabolism where more carbohydrate is synthesized and increases the bulb weight and the total yield. Similarly, Negash et al (2009) found out that application of 92 kg N ha^{-1} resulted in the the highest bulb yield of onion. Birhanu et al (2014) too indicated that higher marketable and total bulb yields from theapplication of nitrogen.

Table 2. Main effects of nitrogen and phosphorus fertilizers on plant height, number of leaves and bulb fresh weight

Treatments	Bulb length (cm)	Bulb diameter (cm)	Marketable bulb yield (kg ha^{-1})
Nitrogen (kg ha^{-1})			
0	3.607	4.931c	16689b
23	3.778	5.366b	19760a
46	3.760	5.565a	20559a
69	3.767	5.592a	21031a
92	3.772	5.586a	20435a
115	3.736	5.636a	19176a
LSD	ns	0.2887	1770.0
Phosphorous (kg P_2O_5 ha^{-1})			
0	3.677	5.370	18581
46	3.747	5.444	19797
69	3.743	5.439	19374
92	3.775	5.481	19688
115	3.765	5.454	20043
138	3.714	5.489	20167
LSD	ns	Ns	ns
CV (%)	10.5	10.3	29.4

Table 3. Nitrogen and phosphorus interaction effect on marketable bulb yield of Onion.

Nitrogen (kg N ha$^{-1)}$	Phosphorus (kg P_2O_5 ha^{-1})	Marketable bulbt yield (kg ha$^{-1)}$
0	0	15099g
	46	17317cdefg
	69	16780 efg
	92	16351 fg
	115	17703cdefg
	138	16902efg
23	0	18342abcdefg
	46	17375cdefg
	69	21830abcdef
	92	17880 cdefg
	115	21065abcdef
	138	22087abcde
46	0	18460abcdefg
	46	23721ab
	69	19895abcdefg
	92	22803abcd
	115	18390abcdefg
	138	20049 abcdefg
69	0	18102cdefg
	46	21516abcdef
	69	18793abcdefg
	92	23811 a
	115	22946abc
	138	21039abcdef
92	0	21054abcdef
	46	20238abcdefg
	69	20039abcdefg
	92	20067abcdefg
	115	18565abcdefg
	138	22668abcd
115	0	20446abcdefg
	46	18635abcdefg
	69	18926abcdefg
	92	17237defg
	115	21610 abcdef
	138	18163bcdefg
	Mean	19608
	CV (%)	28.1
	LSD (0.05)	1477.2

Marketable bulb yield were affected significantly due to the interaction effect of nitrogen and phosphorus in the study area (Table 3). The highest marketable bulb yield (23.81 t ha^{-1} ha) was recorded at application of 69 kg N ha^{-1} N and 92 kg P_2O_5 ha^{-1}. This may be due to the fact that these two important plant nutrients have complementary physiological functions in plants. Moreover, they are the major constituents of physiologically active organic compounds in the plant system, leading to a combined increase in bulb yield. The lowest marketable bulb yield of 15 t ha^{-1} was obtained in the control.

Conclusion and Recommendation

Onion is one of the most important high market value bulb crops cultivated commercially in most parts of the world. It is the most cultivated high market value from among the vegetable crops in Tigray, Northern Ethiopia. However, bulb yield of onion is limited due to low fertility of soil and inappropriate fertilizer rate. The different phenological and yield related traits were examined against various rates of nitrogen and phosphorus fertilizers and their rates. The main effects of nitrogen caused significant variation in plant height, bulb fresh weight and bulb diameter and the main effects of phosphorus caused significant variation only on plant height. Nitrogen and phosphorus interaction had significant effect on marketable bulb yield and the highest marketable bulb yield per hectare was obtained from the combination of 69 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1}. Moreover, further investigations are needed in different soil types including other agronomic management practices to identify best technologies that improve productivity and quality of onion.

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2.4. Effect of NPSKZnB Blended Fertilizer on Yield and Yield Components of Hot Pepper (*Capsium spp*.) in Northwestern Tigray, Ethiopia

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Abstract

Fertilizer use was based on very general or single recommendation for all crop types, which may also lead to low economic return. Nutrients in the blanket recommendation are not well balanced. Hence, this study was initiated to evaluate and determine optimum blended fertilizer rate for hot pepper production. Field experiment was carried out during the year 2016/17cropping season at Tahtay Koraro and Laelay Aadyabo districts of the Tigray regional state, Northern Ethiopia under irrigation condition. The experiment was conducted in a randomized complete block design with three replications consisiting of seven treatments of NPKSZnB levels (25, 50, 100, 150, 200, 250 and 300 kg N ha^{-1}NPKSZnB). Surface soil samples were collected before pepper planting and analyzed for selected soil properties. Application of different NPKSZnB rates under irrigation condition significantly influenced crop phenology, yield and yield components of hot pepper. Highest mean hot pepper yields of 7105.3 and 7675kg ha^{-1} were obtained in response to application of 300 kg ha^{-1} blended fertilizer at both Tahtay Koraro and Laelay Adyabo districts, respectively. However, blended NPKSZnB fertilizer rates of 150 and 50 kg ha^{-1} were found to be economical to improve productivity of pepper under irrigated conditions. Therefore, farmers at both districts are advised to apply the blended NPKSZnB fertilizer at these rates in order to improve productivity of hot pepper.

Keywords: Hot-pepper, blended fertilizer, yield

Introduction

Economic return of fertilizer application is low though there is practice of fertilizer application nationwide. This is because the fertilizer recommendation in Ethiopia was based on a very general guideline or more often a single recommendation for all crop and soil types. With initial understanding that nitrogen and phosphorus are the major limiting nutrients in Ethiopian soils, 150 kg ha^{-1}urea (69-0-0) and 100 kg ha^{-1}DAP (18-46-0) were recommended for all soil and crop types under irrigation (Wassie and Tekalign 2013). This blanket recommendation often fails to take into account the differences in resource endowment (soil type, climate) and make allowances for dramatic changes in input/output price ratio. This discouraged farmers from using fertilizers onto their soil.

Moreover, the nutrients in the blanket recommendation are not well balanced. Continued use may gradually exhaust soil nutrient reserves. Absence of one or more nutrients besides N and P can depress yield significantly. This could explain, in part, the modest crop yield improvements observed over the last few decades in contrast to significant increases in fertilizer use and investment made in the country. Today, in addition to N and P; there exists a widespread deficiency of S, B and Zn in Ethiopian soils, while some soils are also deficient in K, Cu, Mn and Fe (EthioSIS 2014). Therefore neither yields nor profits can be sustained using imbalanced application of fertilizers, as the practice results in accelerating deficiencies of other soil nutrients.

Integrated use of suitable fertilizer types and cropping system is key for sustainable crop production as proper combination of fertilizers and cropping system can increase crop yield by 50% (Zia et al 1991). Better and matching fertilizer recommendations to local climate, soil, and management practices helps ensure that production can be intensified in a cost-effective and sustainable way and, thereby, enhances regional as well as national food security. Hence the objective of this study was to promote sustainable production of the hot pepper through development of soil-specific blended fertilizer recommendation and determine optimum fertilizer rates that would result in the highest yield and return from hot pepper cultivation..

Materials and Methods

Site description

The experiment was conducted for two consecutive seasons of 2016 and 2017 under irrigated conditions on two selected farmer's fields at Tahtay Koraro (Mai-dmu irrigation scheme) and Laelay Adyabo (Meskebet irrigation scheme) districts of North Western Tigray, Northern

Ethiopia. These areas predominantly lie under semi-arid tropical belt of Ethiopia with a hot to warm agro-climatic zone, mono-modal and erratic rainfall pattern. Mai-dmu and Meskebet irrigation schemes are found at around 30 km away to the west of Shire Indasilassie town ($14^{0}6$ N and $38^{0}17$ E) and 15 km away to the southeast of Adi-daero town, respectively. Adi-daero is around 30 km North Western of Shire Indasilassie town.

Experimental design, treatments and procedures

The study sites were selected taking into consideration the blended fertilizer (NPKSZnB) recommendations of Ethiosis (2014). Seven treatments (25, 50, 100, 150, 200, 250, 300 kg NPKSZnB ha^{-1}) were formulated. The treatments were laid out in Randomized Complete Block Design (RCBD) with three replications. Plot size was 3 by 3 meters and hot pepper was planted in rows, replicated 3 times on site and across two farmers' fields of each districts. Additional N was applied as basal to each plot at a rate of 69 kg N ha^{-1} because it was low in the study sites and the content in the blended fertilizers might not satisfy the need of the crop. Blended fertilizers and half of N were applied at planting while the rest of N was top-dressed 30 to 45 days after planting. The test crop (Var. Melka Shetie) was also planted with a spacing of 30, 70, 50 and 100 cm between plants, rows, plots and replications, respectively. The other crop management practices were applied as per the recommendation for the crop.

Soil analysis

Before planting one representative composite soil sample was taken at a depth of 0 - 30 cm from each study sites and farmer's fields using an auger. The collected samples were properly labeled, packed and transported to Shire Soil Research Center. Particle size distribution was determined using the Bouyoucos hydrometer method (Bouyoucos, 1962). The pH of the soil was measured in the supernatant suspension of 1: 2.5 soils to water ratio using a pH meter (Rhoades, 1982). Electrical conductivity (EC) of 1:25 soil to water suspension was measured according to the method described by Jakson (1967). Organic carbon was determined by the Walkely and Black

(1934) method while total N using the Kjeldahl method as described by Bremner and Mulvaney (1982). Available P was determined following the Olsen method (Olsen et al. 1954).

Crop data collection

Agronomic data like planting date, days to flowering, and 50% pod setting, pod length, pod diameter, pod weight, plant height and days to maturity were collected were collected.

Data analysis

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

Partial budget analysis

To assess the costs and benefits associated with the different treatment rates, partial budget technique of CIMMYT (1988) was applied to economic yield. 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 10% lower than those obtained by the researchers if the experiments are planted on representative farmers' fields (CIMMYT 1988).

Results and Discussion

Experimental soil characteristics before planting

Some of the selected soil physical and chemical properties of the experimental sites are indicated in table 1. The soils from Tahtay Koraro are sandy loam in texture while that of Laelay Adyabo is clayey. Soil pH from Tahtay Koraro was moderately acidic while from Laelay Adyabo was neutral according to the rating of Tekalign (1991). Both sites soil were non-saline in their nature. The cation exchange capacity (CEC) of Tahtay Koraro soils were low while that of Laelay Adyabo was high in its CEC with low exchangeable K in both the sites according to Landon (1991). The soil organic carbon and total N were low in both sites according to the rating of Tekalign (1991). Available P was low in the soil of Tahtay Koraro while Laelay Adyabo soil had medium available P (Olsen 1954).

Table 1. Surface (0-30 cm) soil properties of the experimental soils

Soil properties	Tahtay Koraro	Laelay Adyabo
Clay (%)	8	59
Silt (%)	38	23
Sand (%)	54	18
Textural Class	Sandy Loam	clayey
Bulk density (g cm^{-3})	1.43	1.31
pH	6.3	7.05
EC (dS m^{-1})	0.27	0.42
CEC (cmol(+) kg^{-})	25.7	51
OC (%)	0.60	0.73
Total N (%)	0.058	0.078
Available P (mg kg^{-1})	4.5	6.5
Exc.K (cmol(+) kg^{-1})	0.24	0.33

Effects of NPKSZnB fertilizer on phenology, growth parameter and yield of hot pepper

Plant height was not significantly affected by rates of blended fertilizer but pod length was significantly affected by the levels of blended fertilizers at Tahtay Koraro (Table 2). The longest pods were recorded at 150 kg NPKSZnB ha^{-1}() while the shortest pod was obtained from 100 kg NPKSZnB ha^{-1}. At Laelay Adyabo pod length and plant height were significantly ($p \leq 0.05$) affected by different blended fertilizer rates (Table 2). The longest plants (49.93 cm) was recorded in plots that received 300 kg NPKSZnB ha^{-1} while the shortest plants(38.07cm) were recorded in plots that received 100 kg NPKSZnB ha^{-1}. The longest and shortest pods were recorded in plots that received blended fertilizer rates of 50 kg NPKSZnB ha^{-1} and 150 kg NPKSZnB ha^{-1}. Pod number and pod weight of hot pepper were however not significantly affected by the different levels of blended fertilizer at Tahtay Koraro and Laelay Adyabo sites (Table 3).

Table 2. Pod length and plant height of hot pepper as influenced by NPKSZnB fertilizer rate under irrigation condition

Fertilizer rate (kg ha^{-1})	Two years result combined for each district			
	Tahtay Koraro		Laelay Adyabo	
	PL (cm)	PH (cm)	PL (cm)	PH (cm)
25 NPKSZnB (kg ha^{-1})	8.68ab	39.90	9.8667^{ab}	43.533^{ab}
50 NPKSZnB (kg ha^{-1})	8.62ab	43.83	10.4333^{a}	45.667^{ab}
100 NPKSZnB (kg ha^{-1})	8.17b	41.07	9.2667^{b}	38.067^{b}
150 NPKSZnB (kg ha^{-1})	9.07a	44.13	8.7667^{b}	42.067^{ab}
200 NPKSZnB (kg ha^{-1})	8.71ab	42.07	9.6333^{ab}	43.133^{ab}
250 NPKSZnB (kg ha^{-1})	8.84ab	42.93	9.0000^{b}	45.133^{ab}
300 NPKSZnB (kg ha^{-1})	8.40ab	43.43	9.6333^{ab}	49.933^{a}
Mean	8.64	42.48	9.514286	43.93333
LSD	0.85	NS	1.1076	11.263
CV (%)	8.41	11.70	6.647431	14.63983

PL= pod Length and PH= Plant Height

Table 3. Number of pods and pod weight of hot pepper as influenced by NPKSZnB fertilizer rate under irrigation condition

Fertilizer rate (kg ha^{-1})	Two years result combined for each district			
	Tahtay Koraro		Laelay Adyabo	
	PN (number)	PW (g)	PN (number)	PW (g)
25 NPKSZnB (kg ha^{-1})	65.53	9.50	37.67	23.33
50 NPKSZnB (kg ha^{-1})	74.73	10.47	40.33	26.67
100 NPKSZnB (kg ha^{-1})	63.27	11.41	37.67	20.00
150 NPKSZnB (kg ha^{-1})	79.40	11.94	50.00	23.33
200 NPKSZnB (kg ha^{-1})	83.27	12.01	51.00	23.33
250 NPKSZnB (kg ha^{-1})	75.70	12.01	43.67	26.67
300 NPKSZnB (kg ha^{-1})	79.93	11.39	47.00	26.67
Mean	74.55	11.25	43.90	24.29
LSD	NS	NS	NS	NS
CV (%)	21.77	20.92	19.23688	26.96

PN= Pod Number and PW= Pod weight (g)

Blended fertilizer significantly influenced 50% pod setting at Tahtay Koraro but not at Laelay Adyabo (Table 4). Plots that received 150 kg ha^{-1}NPKSZnB set pod earlier than the other treatments, while longest days to set pods were recorded for 25 kg NPKSZnB ha^{-1} at Tahtay Koraro. Days to pod maturity were significantly affected by the rates of the blended fertilizer at Laelay Adyabo but not at Tahtay Koraro and plots that received 300 kg NPKSZnB ha^{-1} took 76.7 days to mature at Laelay Adyabo.

Table 4. Days to hot pepper pod setting and maturity as influenced by blended NPKSZnB fertilizer rates under irrigation condition

Fertilizer rate (kg ha^{-1})	Two years result combined for each district			
	Tahtay Koraro		Laelay Adyabo	
	PS (days)	PM (days)	PS (days)	PM (days)
25 NPKSZnB (kg ha-^{1})	51.33b	83.83	84.00	78.00ab
50 NPKSZnB (kg ha-^{1})	51.33b	83.17	82.67	77.67ab
100 NPKSZnB (kg ha-^{1})	50.0ab	84.00	84.00	79.33b
150 NPKSZnB (kg ha-^{1})	48.17a	81.50	84.00	78.33ab
200 NPKSZnB (kg ha-^{1})	50.3ab	82.17	83.00	76.00a
250 NPKSZnB (kg ha-^{1})	50.20ab	81.83	83.33	77.00ab
300 NPKSZnB (kg ha-^{1})	49.30ab	83.00	83.33	76.67a
Mean	50.10	82.79	83.48	77.57
LSD	3.09	NS	NS	2.59
CV (%)	5.26	3.58	1.69	1.91

50% PS= Pod setting and PM= Pod Maturity

Application of blended fertilizer significantly influenced marketable yield of hot pepper at Tahtay Koraro and Laelay Adyabo (Table 5). Treatments that received 300 kg NPKSZnB ha^{-1} had highest marketable yield of 7105.3 and 7675 kg ha^{-1} at Tahtay Koraro and Laelay Adyabo, respectively and the lowest marketable yields at 25 kg NPKSZnB ha^{-1} application in both districts.

Table 5. Yield of hot pepper as influenced by blended NPKSZnB fertilizer rates under irrigation condition

Fertilizer rate (kg ha^{-1})	Two years result combined for each district	
	Tahtay Koraro	Laelay Adyabo
	MY (kg)	MY (kg)
25 NPKSZnB (kg ha-^{1})	2258.8 d	5482^{ab}
50 NPKSZnB (kg ha-^{1})	3662.3 c	7149^{a}
100 NPKSZnB (kg ha-^{1})	2412.3 d	4211^{b}
150 NPKSZnB (kg ha-^{1})	6557.0 a	4956^{ab}
200 NPKSZnB (kg ha-^{1})	6644.7 a	5746^{ab}
250 NPKSZnB (kg ha-^{1})	5263.2 b	6579^{ab}
300 NPKSZnB (kg ha-^{1})	7105.3a	7675 ^{a}
Mean	4843.358	5971.18
LSD (0.05)	1210.8	2723.1
CV (%)	21.33	26.04

MY= Marketable yield

Partial budget analysis

Hot pepper yield was significantly affected by the different rates of NPKSZnB. Hot pepper yield increased with increased NPKSZnB rates except for some inconsistencies (Tables 5 and 6). Furthermore, maximum hot pepper yield 7105.3 and 7675 kg ha^{-1} and net benefit of 218142.0 and 236087.6 ETB ha^{-1} was recorded from plots that received 300 kg NPKSZnB ha^{-1} at Tahtay Koraro and Laelay Adyabo districts, respectively.

Marginal rate of return (MRR) between 50% and 100 % is the minimum acceptable rate of return for a treatment to be considered as a useful option to farmers according to CMMYT (1988). In this experiment, highest marginal rate of return of 140.79 and 109.45 % were obtained from plots that received 150 and 50 kg NPKSZnB ha^{-1} at Tahtay Kkoraro and Laelay Aadyabo districts, respectively (Tables 6). Therefore, application 150 and 50 kg NPKSZnB ha^{-1} with 69 kg N ha^{-1} to hot pepper could be profitable for farmers in both district and other areas having similar agro-ecologies.

Conclusion and Recommendation

Fertilizer application for vegetable crops under irrigation condition has been practiced for a long time in the two districts. However, the yield and economic return was decreasing from time to time due to the use of the blanket fertilizer recommendation for different crops. Furthermore, the blanket recommendation has unbalanced nutrient constituents which make it agronomically inefficient. Therefore, this study was initiated to promote sustainable increase of hot pepper yields through development of crop and soil-specific fertilizer recommendation.

Maximum pepper yield was recorded with application of 300 kg NPKSZnB ha^{-1} fertilizer at Tahtay Koraro and Laelay Adyabo. However highest marginal rate of returns were recorded from application of 150 and 50 kg NPKSZnB ha^{-1} at Tahtay Kkoraro and Laelay Aadyabo districts, respectively. Therefore, application 150 and 50 kg NPKSZnB ha^{-1} with 69 kg N ha^{-1} to hot pepper could be profitable for farmers in both district and other areas having similar agro-ecological conditions. Iit can be concluded that for better production of hot pepper the nutrients other than N and P in the blended fertilizer (NPKSZnB) might have improved yield and yield components of hot pepper. Researchers can also benchmark the rates for further study in different soil and crop conditions. Besides further study on blended fertilizers without K is needed because K in the blend might not be enough for the crop demand or may be affected by fixation.

Table 6. Partial budget analysis of Determination of balanced fertilizer rate on yield and yield components of hot-pepper at Tahtay Koraro and Laelay Adyabo

Fertilizer rate (kg K/ha)	FC (Birr)	TLC [Birr]	TVC [Birr]	MY (kg/ha)	AjY (kg/ha)	TR [Birr]	NR [Birr]	MRR (ratio)	MRR (%)
				Tahtay Koraro					
25 NPKSZnB (kg ha-^{1})	445.41	30	475.41	2258.8	2032.92	71152.2	70676.8	0	0
50 NPKSZnB (kg ha-^{1})	890.82	60	950.82	3662.3	3296.07	115362.5	114411.6	91.99394	9199.394
100 NPKSZnB (kg ha-^{1})	1781.64	120	1901.64	2412.3	2171.07	75987.45	74085.8	D	D
150 NPKSZnB (kg ha-^{1})	2672.46	150	2822.46	6557	5901.3	206545.5	203723.0	140.7846	14078.46
200 NPKSZnB (kg ha-^{1})	3563.28	210	3773.28	6644.7	5980.23	209308.1	205534.8	D	D
250 NPKSZnB (kg ha-^{1})	4454.1	270	4724.1	5263.2	4736.88	165790.8	161066.7	D	D
300 NPKSZnB (kg ha-^{1})	5344.92	330	5674.92	7105.3	6394.77	223817	218142.0	D	D
				Laelay Adyabo					
25 NPKSZnB(kg ha-^{1})	445.41	30	475.41	5482	4933.8	172683	172207.6	0	0
50 NPKSZnB(kg ha-^{1})	890.82	60	950.82	7149	6434.1	225193.5	224242.7	109.45	10945.31
100 NPKSZnB(kg ha-^{1})	1781.64	120	1901.64	4211	3789.9	132646.5	130744.9	D	D
150 NPKSZnB(kg ha-^{1})	2672.46	150	2822.46	4956	4460.4	156114	153291.5	24.49	2448.54
200 NPKSZnB(kg ha-^{1})	3563.28	210	3773.28	5746	5171.4	180999	177225.7	D	D
250 NPKSZnB(kg ha-^{1})	4454.1	270	4724.1	6579	5921.1	207238.5	202514.4	D	D
300 NPKSZnB(kg ha-^{1})	5344.92	330	5674.92	7675	6907.5	241762.5	236087.6	D	D

FC= Fertilizer cost, TLC= transport and labor cost, TVC= Total variable cost, MY= marketable yield, AjY= Adjested yield, TR= Total Revenue, NR= Net revenue and MRR= marginal rate of return.

Note:-TVC = FC + TLC

AjY = MY- (MY*10%)

NR = TR-TVC

MRR= MRR is the ratio of $(NR_n-NR_{n-1})/(TVC_n-TVC_{n-1})$ *where n is number of treatments*

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2.5. Effects of Mineral Nitrogen and Phosphorus Fertilizer Rates on Growth, Yield and Yield Components of Tomato *(Lycopersicon esculentum* Mill*)* in the North Western Zone of Tigray, Ethiopia

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Abstract

Field experiments were conducted at Shire-Maitsebri Agricultural Research Center on station with the objectives of evaluating the effects of N and P fertilizer applications on growth and yield, and determining optimal requirements for tomato. The experiments were conducted under irrigation conditions in the off season. The treatments consisted of six rates of nitrogen (0, 23, 46, 69, 92 and 115 kg N ha^{-1}) and six rates of P (0, 46, 69, 92, 115 and 138 kg ha^{-1}). The experiments were laid out in a factorial randomized complete block design (RCBD) with three replications. The tomato variety used for the experiment was Melkasalsa. Results of the experiment showed significant differences in tomato marketable yield and plant height among the different fertilizer treatments. Treatment that combines 115 kg Nha^{-1} and 92 kg P_2O_5 ha^{-1} resulted in highest marketable yield and taller plants. Nitrogen showed significant differences in marketable tuber yield under the same phosphorus level indicating that the effect of different levels of phosphorus on marketable fruit yield is dependent on the levels of nitrogen. This may be due to the positive interaction and complementary effect between nitrogen and phosphorus in affecting and increasing the marketable tuber yield of tomato in the study area.

Keywords: Nitrogen, phosphorus, yield, tomato

Introduction

Tomato *(Lycopersicon esculentum Mill)* is one of the most popular, important and widely used vegetable crops following potato in the world (Dorais et al 2008 and Olaniyi et al 2010). It is considered a perennial crop, but for commercial productions it is cultivated as an annual crop (Mohamed et al 2010).

Tomato can be source of cash and indirectly secure food of smallholder famers through commercialization of agriculture in Ethiopia. Food security for the rapid expanding population is a big challenge and can only be achieved by increasing crop productions and healthy foods. Food security cannot be attained without availability of essential plant nutrients to growing crops (Chen 2006 and Ali et al 2008). Therefore, plant nutrients are the essential component of sustainable agriculture. Undoubtedly, for optimum plant growth and production, the essential nutrients must be readily available in sufficient and balanced quantities. The readily available sources, which provide essential nutrients and maintain a favorable balance, are chemical fertilizers.

In Ethiopia, farmers get lower yield mainly due to diseases and pests as well as due to sub-optimal fertilization. Mehla et al (2000) and Pandey et al (1996) reported that fruit yield in tomato is highly influenced by N and P fertilizers. Similarly, Sherma et al (1999) reported average fruit weight of tomato to have been influenced by the amount of N and P fertilizers. Thus, tomato plant should receive optimum amount of N and P to produce higher fruit yields. The total nitrogen (kg ha^{-1}) and P_2O_5 (kg ha^{-1}) required to achieve target fruit yields are estimated by multiplying the target yield in tons per hectare by 2.4 and 0.35, respectively (http://www.avrdc.org 2007).

It is well documented that application of N promotes vegetative growth and fruit yield of tomato, and later application in the growing stages favors fruit development, thus nitrogen has a dramatic effect on tomato growth and development in soils with limited N supplies such as sandy soils (Hokam et al 2011). Similarly, application of phosphorus is an important nutrient for tomato plant growth and development and deficiency of P leads to reduced growth and reduced yields (Hochmuth et al 2009). Tomatoes have the greatest demand for phosphorus at the early stages of development (Csizinszky 2005).

Among the field management practices, applications of Urea and DAP fertilizers have significant and positive relationship with fruit yield. However, tomato growers in the North Western zone of Tigray apply variable rates of N and P fertilizers, probably does not meet crop requirements

(Taha 2007). Thus determination of optimum mineral N and P fertilizer rates for tomato production is required to obtain maximum yield and quality. Therefore, field experiments were conducted with the objectives of evaluating the effect of mineral N and P fertilizer applications on growth and yield and determine the optimal N and P levels under furrow irrigated conditions at North Western zone of Tigray.

Materials and Methods

Field experiments were conducted during 2016-2017 under irrigation condition in northwestern Zone of Tigray at Tselemti and Tahtay Koraro districts and in the experimental Stations of Shire-Maitsebri Agricultural Research Center (SMARC). The experiment was laid out in a factorial randomized complete block design (RCBD) with three replication. The experiment consisted of six nitrogen (0, 23, 46, 69, 92 and 115 kg N ha^{-1}) and six phosphorus (0, 46, 69, 92, 115 and 138 kg P_2O_5 ha^{-1}) levels. Each treatment combination was assigned randomly to the experimental units within a block. There were 36 plots corresponding to the 36 treatment combinations. The plot size of the experiment was 3.75 m x 1.8 m (7.5 m^2). The blocks were separated by a distance of 2 m and space between each plot within a block was 1.0 m. There were 5 rows in each plot and the central three rows were used for data collection, considering the two outermost rows as border. The testing variety was Melkasalsa. The seeds of ‘Melkasalsa’ variety were raised on nursery for about 30 days. All management practices for the crop were applied uniformly as per the recommendation during nursery and field conditions.

Plant height was measured from the ground level to the top at the end of mid stage of the crop growth using a ruler from six sample plants in each plot. Marketable fruit yield per plant (kg) was estimated from average weight of healthy and marketable tagged six plants in six harvests. Total marketable fruit yield per plot and hectare were estimated from marketable yield per plant.

Collected data were subjected to two way analysis of variance (ANOVA) following a procedure appropriate to randomized complete block design (Gomez and Gomez, 1984). When there were treatment differences, least significance differences (LSD) test was used to separate the means.

Results and Discussion

The interaction effect of nitrogen and phosphorous were found significant ($p<0.05$) on plant height and marketable fruit yield of tomato (Table1).

Plant height

Plant height is an important growth character directly linked with productive potential of plants in terms yield. Tallest plants were observed in treatment that combined 115 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1}. This may be due to the synergist effect of both nutrient sources. Increasing N from 0 to 115 kg N ha^{-1} increased plant height consistently. As compared to the check treatment, the increment ranged up to 14.5%. This increment in plant height due to N and P fertilizations may be due to the increase in cell elongation. Rao and Dao (1992) and Gautam and Kaushik (1982) also reported significant increase in plant height of finger millet with N application. Tenaw (2000) also reported a significant effect of N fertilizer on height of maize.

Marketable fruit yield

The data presented in table 1 revealed that significantly higher marketable yield (61167 kg ha^{-1}) of tomato was obtained from plots that received relatively higher amount of nitrogen and phosphorus. Plots fertilized with 115 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} produced maximum marketable fruit yield of 61167 kg ha^{-1} of tomato followed by 92 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} application. Hegde (1986) and Shukla et al (1989) also reported yield increase with increasing nitrogen levels. Nitrogen showed significant differences in marketable yield under the same phosphorus level indicating that the effect of different levels of phosphorus on marketable fruit yield is dependent on the levels of nitrogen. This may be due to the positive interaction and complementary effect between nitrogen and phosphorus in increasing the marketable yield of tomato in the study area. Similarly, FAO (2000) reported without phosphorus application, nitrogen efficiency declined thereby indicating interaction between the nutrients

Table 1. Interaction effect of nitrogen and phosphrous fertilizers on plant height and marketable fruit yield of tomato

Nitrogen (kg N ha$^{-1)}$	Phosphorus (kg P_2O_5 ha^{-1})	Plant height (cm)	Marketable fruit yield (kg ha$^{-1)}$
0	0	48.22abcdef	29799efg
	46	44.96def	27388 g
	69	44.18ef	29286fg
	92	43.46f	29760efg
	115	44.85def	33888defg
	138	46.74bcdef	33972defg
23	0	47.90bcdef	36130cdefg
	46	49.07abcdef	47280abcd
	69	47.74bcdef	44301 abcdefg
	92	49.35abcdef	48788abcd
	115	48.94abcdef	48589abcd
	138	48.35abcdef	42498bcdefg
	46	46.06cdef	39864 bcdefg
	69	53.28ab	48258abcd
	92	50.47abcdef	41355bcdefg
	115	50.33abcdef	54046ab
	138	50.36abcdef	46358abcdef
69	0	48.87abcdef	39580bcdefg
	46	48.54abcdef	47680abcd
	69	49.95abcdef	43697 bcdefg
	92	51.09abcde	46852abcde
	115	52.68abc	55052 ab
	138	51.69abcd	47613abcd
92	0	48.44 abcdef	39936bcdefg
	46	50.62abcde	52982 abc
	69	51.14abcde	44219abcdefg
	92	52.84abc	55336ab
	115	49.73abcdef	49057abcd
	138	51.69abcd	48648abcd
115	0	46.86bcdef	43415bcdefg
	46	51.66abcd	47635abcd
	69	49.98abcdef	47933abcd
	92	55.28a	61167a
	115	51.08abcde	53549abc
	138	51.69abcd	45457abcdef
	LSD	5.632	13973.9
	CV (%)	12.3	34.0

Conclusion and Recommendation

Tomato is among the most important vegetable crops in Ethiopia in general and North Western zone of Tigray in particular. However, tomato production in Ethiopia and North Western zone of Tigray is highly constrained by several factors mainly inappropriate agronomic practices and lack of improved variety. Improper application of plant nutrients (especially the macro nutrients) is among the notable reasons for low productivity of tomato. Plant nutrients greatly influenced growth, yield, and quality parameters both in fresh and processed tomatoes. Treatment that combined 115 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} resulted in highest marketable yield and taller plants. Nitrogen showed significant differences in marketable fruit yield under the same phosphorus level indicating that the effect of different levels of phosphorus on marketable fruit yield is dependent on the levels of nitrogen. This may be due to the positive interaction and complementary effect between nitrogen and phosphorus in affecting and increasing the marketable fruit yield of tomato in the study area. Moreover further similar investigations are needed in different soil types including other agronomic management practices to identify best technologies for improved productivity and quality of tomato.

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2.6. Effects of Nitrogen on Yield and Yield Components of Wheat (*Triticum aestivum* L.) under NPSB Blended Fertilizer in Tsegede and Welkait Districts, Western Zone, Tigray, Ethiopia

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Abstract

Decisions concerning optimum rates of fertilization directly involve fitting some type of rates to yield when several rates of fertilizer are tested. This study was carried out to investigate the effects of nitrogen fertilizer rates on yields and yield components of bread wheat and determine optimum rate of N. The field experiment was carried out in 2016 and 2017 main cropping season at Tsegedie and Welkait districts in Western Zone, Tigray Regional State, Ethiopia. The experiment consists of seven levels of nitrogen (0, 23, 46, 69, 99, 115 and 138 kg ha^{-1}) arranged in a randomized complete block design with three replications. Nitrogen was applied in splits, half at planting and remaining at tiller stage. NPSB was applied as basal application for all experimental plots except the negative control. Soil samples were collected before planting for analysis of some selected physicochemical properties. The soil properties of the experimental sites of the two districts varied in most of the soil properties. Application of nitrogen significantly influenced grain yield and yield components of wheat in both study sites. The highest grain yields of 3926 kg ha^{-1} and 2131 kg ha^{-1} were obtained from 138 kg N ha^{-1} and 115 kg N ha^{-1} at the study sites of Tsegedie and Welkait districts, respectively. Highest marginal rate of returns were however obtained at nitrogen rates of 46 kg ha^{-1} and 23 kg ha^{-1} at Tsegedie and Welkait districts, respectively. Hence, it could be concluded that the use of N at 46 kg ha^{-1} and 23 kg ha^{-1} with 100 kg NPSB fertilizer could give optimum bread wheat yield at Tsegedie and Welkait districts, respectively.

Keywords: Wheat, nitrogen, yield, tsegede

Introduction

Wheat (*Triticum aestivum* L.) is a major staple of the global population and also a very versatile crop that shows wide adaptation to diverse agro-ecological conditions and cropping technologies (Pena 2007). High quality seed of wheat is the key to successful agriculture (Mladenov et al 2012). Wheat is a staple and the primary source of calories for over 1.5 billion people in the world. It has been intensively grown throughout the twentieth century and even now constitutes over a major part of the cereal output (Reynolds et al 1999).

In Ethiopia, low soil fertility is one of the factors limiting the yield of crops, including wheat. It may be caused as a result of removal of surface soil by erosion, crop removal of nutrients from the soil, total removal of plant residue from farmland and lack of proper crop rotation program (Tamirie 1982). Soil nitrogen (N) is frequently deficient in continuous mono-cropping cereal production systems (Hanson et al 1982). Maintaining soil fertility and use of plant nutrients in sufficient and balanced amounts is one of the key factors for increasing crop yield (Diacono et al 2013).

Nitrogen is deficient in most agricultural soils and limits crop yield in many regions of the world (Giller 2004). Nitrogen is the first limiting macro-element on many farms where bread wheat (*Triticum aestivum*) has been grown continuously for more than a decade (Wendling et al 2007; Ooro et al 2011 and Kutman et al 2011). It is the most important fertilizer element playing vital role in yield improvement of wheat (Islam 1990). Increasing wheat production to meet higher demands by growing populations is still a challenge in many countries (Sary et al 2009; Abedi et al 2010; Campuzano et al 2012). The most important role of N in the plant is its presence in the structure of protein and nucleic acids, which are the most important building and information substances of every cell. In addition, N is also found in chlorophyll that enables the plant to transfer energy from sunlight by photosynthesis. Thus, N supply to the plant will influence the amount of protein, amino acids, protoplasm and chlorophyll formed. Moreover, N influences the cell size, leaf area and photosynthetic activity (Azeez 2009; Namvar et al 2012; Daneshmand et al 2012; Piccinin et al 2013; Diacono et al 2013). Yet N was reported as the most deficient nutrient in the soils of the study districts of Welkait and Tsegede (EthioSIS 2014). Therefore the current study was conducted to determine the optimum rates of nitrogen for wheat production, promote sustainable intensification of wheat production systems in the Western highlands of Tigray and providing soil series-specific fertilizer recommendations through soil fertility trials based on newly developed soil fertility Atlas of Tigray region.

Materials and Methods

This study was conducted at Tsegede (Tabia Cheguar Kudo) and Welkait (Tabia Degena) districts in western Tigray, North Ethiopia. Welkait district is situated at $36^0$50'29'' - $37^0$20'25''E and $13^0$48'6.6''- $14^0$6'41''N with an elevation range of 700- 2353 meters. Agro ecologies of the district are Dega, Wena Dega and Kola. The mean annual rain fall varies from 700-1800 mm and with maximum and minimum temperatures of 25 ^{0}c and 17.5 ^{0}c, respectively (BoA 2015). Tsegede district is situated at $36^0$510'29'' - $37^0$05'25''E and $13^0$4'25''- $14^0$6'55''N with an elevation range of 700- 3000 masl. Agro ecologies of the district are Dega, Wena Dega and Kola. The mean annual rain fall varies from 700-1800 mm and with maximum and minimum temperatures of 25 ^{0}c and 17.5 ^{0}c, respectively (BoA 2015).

Field experiments were conducted in order to study the response of wheat to different rates of nitrogen fertilizer under the same level of NPSB blended fertilizer in Tsegede (Tabia Cheguar Kudo) and Welkait districts (Tabia Degena). Lime was applied to the experimental fields at Tsegede because soil acidity is common problem in the district. Field experiments were conducted using Randomized Complete Block Design (RCBD) and treatments were replicated three times. The experiments consisted of seven rates of nitrogen (0, 23, 46, 69, 92, 115 and 138 kg ha-^{1}). Nitrogen was applied in splits, half at sowing and the remaining applied 3 weeks after sowing. 100 kg NPSB blended fertilizer was applied based on soil fertility Atlas of the districts (EthoSIS 2014).

The field was prepared well before sowing by ploughing twice with oxen and well leveled for seed bed. Seeds of wheat (*Triticum aestivum L.*) were sowed in rows in plot size of 3 m by 3 m with spacing of 0.2 m between rows. Plots were separated by 1 m and blocks by 1.5 m unplanted distances. All agronomic operations were kept normal and uniform for all treatments. The plants were harvested at maturity and traits such as plant height, number of seeds per panicle and number of tillers plant were recorded on 5 randomly selected plants in each plot. Grain and biological yields were obtained by harvesting an area of 3 m by 2.6 m from the middle of each plot, to avoid border effects. Data analysis was done using GenStat version 16 computer software packages and comparison of means was investigated using Duncan's Multiple Range Test (DMRT) at 0.05% probability.

Results and Discussion

Selected physicochemical properties of soils of the experimental sites

The soil textural class of both Tsegedie and Welkait districts experimental sites was sandy loam (Table 1). According to FAO (2006) the preferable pH ranges for most crops and productive soils are from 4 to 8. Thus, the pH of the experimental sites soils was within the range for productive soils. According to Tekalign (1991) rating of soil pH, the pH of soils of Cheguar Kudo site in Tsegedie district was strongly acidic and that of Dejena site in Welkait district was neutral. The soil organic carbon and total N contents of both sites was low (Table 1). Azlan et al (2012) also reported that soil texture influences the rate of soil organic matter (SOM) decomposition. Soils with high clay content may have higher SOM content due to slower decomposition of organic matter.

Available phosphorous of soils of Tsegedie site (Cheguar Kudo) was low while it was medium for soil of Welkait Dejana site according to the rating of Cottenie (1980). According to Murphy (1968) rating, CEC was medium for soils of Cheguar Kudo site in Tsegedie district and high for soil of Dejena in Welkait district (Table 1).

Table 1. Initial soil (0-20cm) physical and chemical properties of the experimental fields Tsegedie and Welkait.

District	Textural Class	pH-H_2O	CEC Cmol (+) kg^{-1} soil	OM (%)	Total- N (%)	Available P (mg kg^{-1})
Tsegedie	Sandy Loam	5.2	25.0	0.72	0.040	0.74
Welkait	Sandy Loam	6.6	27.4	0.87	0.041	5.1

Response of wheat yield and yield components to nitrogen fertilizer

Days to maturity

Days to maturity was significantly affected by nitrogen rates. Days to maturity consistently increased with increased nitrogen rates (Table 2). The observed increasing trend in days to maturity could be due to increased rates and the relatively better availability of N from the control plot which could lead to the late maturity of the plant at control. The results obtained from this study were in line with results reported by Abebe (2012) that better availability of N from fertilized plot delayed maturity of wheat crop. The longest days to maturity were recorded for plots that received 138 N kg ha^{-1} and 115 N kg ha^{-1} and the shortest DTM for plots that received zero kg N ha^{-1}. Damene (2003) and Woinshet (2007) also reported that increasing N rates delayed days to maturity of wheat. The longest days to maturity were higher at Cheguar Kudo in Tsegedie compared to that of Dejena site in Welkait. This might be due to higher rainfall in Tsegedie district. Under normal condition crops may take long to maturity to exploit the available moisture and nutrients in the soil.

Plant height

Plant height was significantly affected by rates of nitrogen. Plant height increased with increasing rates of nitrogen in the two sites (Table 2). A difference in plant height was only significant between the control and the other treatments. This may be due sufficient applied nitrogen in soil and abundant amount of rain fall. It was higher for plots that received 115 kg N ha^{-1} in the two districts and the shortest plant height was recorded on plots that received zero kg N ha^{-1}. The results obtained was in line with the findings of Marcelo et al (2014) who stated that there was no significant difference between wheat plant heights on plots treated with different rates of Urea.

Number of tillers per plant

Number of tillers contributes a lot to the total biomass, gain yield and other yield attributes. The analysis of variance showed there was highly significant difference ($p<0.01$) due to the difference in nitrogen rates. The highest numbers of tillers were recorded for plots treated at 115 kg N ha^{-1} and 138 kg N ha^{-1} at Tsegedie and Welkait, respectively (Table 2). The lowest numbers of tillers were recorded for plots that received zero nitrogen. This might be due to the role of N in accelerating vegetative growth of plants. The results were in agreement with Abdullatif et al (2010) who reported that increased number of tillers with increase in nitrogen fertilization. Bereket et al (2014) also reported that nitrogen fertilization have significant effect on number of tillers of wheat.

Table 2. Mean of day to maturity, plant height and number of effective tillers as affected by Urea and fertilizer on wheat.

	Tsegedie (Cheguar Kudo)			Welkait (Dejena)		
Nitrogen levels (kg ha^{-1})	DM	PH (cm)	NTPP	DM	PH (cm)	NTPP
Control	156.5b	67.43b	1.433d	101c	56.04b	0.98b
23	159.3ab	87.63a	1.9c	107.4a	70.31a	2.9b
46	160.7a	74.57ab	2.2bc	107.4a	70.22 a	3.3ab
69	160.2ab	85.23ab	2.7b	106.4bc	70.91 a	3.4ab
92	159.8ab	88.53a	2.4bc	106.3c	72.33 a	3.2ab
115	160.5a	92.87a	3.4a	107.2ab	74.09 a	4.2a
138	160.7a	88.87a	2.8b	107.2ab	70.98 a	3.4ab
CV (%)	0.9	17.5	21.6	0.7	7.3	15.1
LSD(0.05)	2.36	24.6	0.9	1.2925	8.3	1.8

DM = Day to Maturity, PH= Plant Height; NTPP = Number of tillers per plant. Means with the same letter are not significantly different

Number of seeds per panicle

The analysis of variance showed significant difference ($p<0.05$) on number of seeds per panicle due to the effects of sources and rates of nitrogen (Table 3). There was an increasing trend in the number of seeds per panicle. The lowest and highest value was recorded at zero nitrogen treatment and 115 kg N ha^{-1} in both study sites. Similar results have been reported for the influence of Urea on yield and yield components including number of seed per panicle of wheat (Zaman et al 2009).

Grain yield

Grain yield of wheat was significantly influenced ($p < 0.05$) by application of nitrogen fertilizer (Table 3). In both sites, there was inconsistent increment in the amount of grain yield with rates of N. The highest grain yield was recorded from plots treated with 138 kg N ha^{-1} (3926kg ha^{-1}) and 115 kg N ha^{-1} (2131kg ha^{-1}), whereas the lowest was recorded from plots that received zero kg N ha^{-1} (1353 kg $ha^{-1}$and 716 kg ha^{-1}) at Tsegedie and Welkait sites respectively. Bereket et al (2014) also reported that increasing rate of nitrogen fertilization increased grain yield of wheat. Liliana et al (2014) also reported denitrification rate in wheat crop were observed when N fertilizer was applied in areas where rain was more frequent and intensive. Mean grain yield at Cheguar Kudo site in Tsegedie was higher compared with that of Dejena sites in Welkait. This could be due to differences in wheat variety used, soil fertility status and amount of rainfall received.

Table 3. Mean of number of seeds per spike, biomass yield and grain yield as affected by Urea and fertilizer on wheat.

	Tsegedie (Cheguar Kudo)			Welkait (Dejena)		
Nitrogen levels (kg ha^{-1})	$NSPP^{-1}$	BY kg ha^{-1}	GY(kg ha^{-1})	$NSPP^{-1}$	BY kg ha^{-1}	GY(kg ha^{-1})
Control	33.83^{c}	4722^{c}	1353^{c}	34.9^{d}	1826^{d}	716^{d}
23	36.9	6045^{bc}	1938^{bc}	44.8^{c}	3739^{c}	1540^{c}
46	40.4	6054^{bc}	1847^{bc}	45.7^{bc}	3662^{c}	1830^{abc}
69	38.67	8553^{ab}	2863^{ab}	46.23^{bc}	4351^{b}	1884^{ab}
92	42.57	5709^{bc}	2786^{ab}	49.8^{ab}	4673^{ab}	1790^{bc}
115	44.93	8492^{a}	3432^{a}	53.8^{a}	5278^{a}	2131^{a}
138	40.17	9239^{a}	3926^{a}	51.33^{a}	5188^{a}	2119^{a}
CV (%)	22.3	27.2	25.5	9	14.8	17.6
LSD (0.05)	21.7	3046.4	1081.2	6.9	999.2	499.1

NSPP = number of seeds per panicle, BY= biomass yield and GY = grain yield. Means with the same letter are not significantly different

Biomass yield

Biomass yield was affected by the rates of N ($p< 0.05$) in both sites (Table 4). At both site, biomass yield showed increasing trend eventhough there are some inconsistencies. The lowest biomass yields were obtained from control plots with no nitrogen treatments (4722 kg $ha^{-1}$and 1826 kg ha^{-1}) and the highest from plots that received 138 kg N ha^{-1} and 115 kg N ha^{-1} (9239 kg ha^{-1} and 5278 kg ha^{-1}) in Cheguar Kudo site in Tsegedie and Dejena in Welkait, respectively (Table 3). Similarly, Abebe (2012) and Bereket et al (2014) reported that wheat straw yield increased with N rates.

Partial budget analysis of nitrogen rates and sources

The results of MRR of the two districts are presented in Tables 4 and 5. The highest net revenue was obtained from plots fertilized with N rate of 138 kg N ha^{-1} at Cheguar kudo in Tsegedie and 115 kg N ha^{-1} N at Dejena in Welkait. At Cheguar kudo in Tsegedie and Dejena site in Welkait, the highest marginal rate of return was obtained from plots treated with 46 kg N ha^{-1} (1717.44%) N and 23 kg N ha^{-1} (418.76%), respectively. 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%). According to the marginal rate of return at Cheguar kudo 46 kg N ha^{-1} and 23 kg N ha^{-1} at Dejena were found economically profitable compared to other treatments.

Table 4. Partial budget for N rate and blended (NPSB) on Wheat compiled for Tsegedie district

N (kg ha^{-1})	Fertilizer cost (Birr)	Application Cost (Birr)	Total Variable cost (Birr)	Grain Yield adjusted (10%)	Total revenue*12	Net revenue [TR-TVC]	MRR (ratio)	MRR (%)
Control	0	0	0	1217.70	14612.40	14612.40		
23	431.25	172.5	603.75	1744.20	20930.40	20326.65	D	D
46	862.5	345	1207.5	1662.30	19947.60	18740.10	17.17	1717.44
69	1293.75	517.5	1811.25	2576.70	30920.40	29109.15	D	D
92	1725	690	2415	2507.40	30088.80	27673.80	10.56	1055.58
115	2156.25	862.5	3018.75	3088.80	37065.60	34046.85	7.84	783.68
138	2587.5	1035	3622.5	3533.4	42400.8	38778.3	10.70	1070.48

Where N = nitrogen; ha= hectare and MRR= Marginal Rate of Return, D= dominated

Conclusion and Recommendation

Understanding plant nutrient requirement of a given area has vital role in enhancing crop production and productivity on sustainable basis. Excessive use of N fertilizers is economically unfavorable, because incremental increases in yield diminish with increasing amounts of N applied, and it could lead to detrimental effects on the quality of soil and water resources. Therefore, application of nitrogen fertilizer at the right rate is vital for the enhancement of soil fertility and crop productivity. This study was initiated to investigate effects of optimum rate of nitrogen under blended fertilizer (NPSB) for wheat production in Western Tigray.

Table 5. Partial budget N rate and blended (NPSB) on Wheat compiled for Welkait district

N (kg ha^{-1})	Fertilizer cost (Birr)	Application Cost (Birr)	Total Variable cost (Birr)	Grain Yield adjusted (10%)	Total revenue*12	Net revenue	MRR (ratio)	MRR (%)
Control	0	0	0	644.40	7732.80	7732.80		
23	431.25	172.5	603.75	1386.00	16632.00	16028.25	4.1876	418.76
46	862.5	345	1207.5	1647.00	19764.00	18556.50	D	D
69	1293.75	517.5	1811.25	1695.60	20347.20	18535.95	D	D
92	1725	690	2415	1611.00	19332.00	16917.00	D	D
115	2156.25	862.5	3018.75	1917.90	23014.80	19996.05	-1.21	-121.47
138	2587.5	1035	3622.5	1907.1	22885.2	19262.7	3.327	332.7

Where N = nitrogen; ha= hectare and MRR= Marginal Rate of Return, D= dominated

A field experiment was conducted on two locations during the 2016 and 2017 main cropping season at Cheguar kudo site in Tsegedie and at Dejena sites in Welkait district of Tigray Regional state, Ethiopia. Highest grain yield and highest profit were obtained from plots treated with 138 kg N ha^{-1} and 115 kg N ha^{-1} at Cheguar Kudo in Tsegedie and at Dejena in Welkait, respectively. However, the highest marginal rate of return was obtained at 46 kg N ha^{-1} and 23 kg N ha^{-1} at Cheguar Kudo in Tsegedie and at Dejena in Welkait, respectively. Therefore N should be used at the rate of 46 kg ha^{-1}, with basal application of 23 kg ha^{-1} NPSB to boost up bread wheat production and productivity at Tsegedie and Welkait district respectively.

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2.7. Effect of Different Furrow and Plant Spacing on Yield and Water Use Efficiency of Maize

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Abstract

In southern zone of Tigray, Ethiopia, there is a large competition between maize production and other horticultural crops for the limited irrigation water. Hence, there is an imminent need to improve the water use efficiency or more importantly the water productivity of the area. The objective of the study was to evaluate the effect of furrow and plant spacing and their interaction on yield and water use efficiency of maize. Experimental treatments include three levels of furrow spacing (50, 70 and 90 cm) and three levels of plant spacing (20, 25 and 30 cm) and were arranged in factorial randomized complete block design (RCBD) with three replications. Maize (BH543 variety) was used in this study in which all agronomic practices were treated equally including the amount of water applied. Maize water requirement was estimated using CROPWAT 8 software. The result revealed that there was significant difference among the treatments ($p<0.05$) for grain yield, biomass yield and irrigation water use efficiency (IWUE). But it was not significantly different for the yield components (plant height and number of cobs per plant). Maximum grain yield (5626 kg ha^{-1}) and IWUE (0.876 kg m^{-3}) were obtained from 50 cm furrow and 30 cm plant spacing interaction. But maximum biomass yield (25060 kg ha^{-1}) was obtained from 50 cm furrow and 20 cm plant spacing interaction. The IWUE ranges from 0.357 kg m^{-3} to 0.876 kg m^{-3} for the equal amount of irrigation water applied (642 mm) for each treatment. This shows how much IWUE of small scale farmers can vary as their agronomic practice (plant and furrow spacing) is different from one another. Hence, it can be concluded that irrigation agronomist experts and development agents of the study area must create awareness to the small scale farmers to exercise 50 cm furrow spacing and 30 cm plant spacing to improve and increase the water productivity of maize.

Keywords: IWUE, small-scale irrigation, agronomic practice, maize , yield

Introduction

Soil, water, air and sunshine are the four key essential determinants for plant to grow. Therefore, water and its control mechanism are important to plant-growth and crop-production (Widtose 2001). The sources of water for crop production are rainfall and irrigation water. The two types of agriculture seen from the perspective of water management are rain-fed and irrigation agriculture which both helps to present sufficient water in the root zone for germination, evapo-transpiration and nutrient absorption (Dupriez and De Leener 2002).

Currently the Ethiopian government considers water as an essential policy instrument for development especially in ensuring food security of the rural population (Fitsum et al 2009). As strategic intervention of addressing food security in Ethiopia, the government and the cooperating sponsors has been chosen intensification of small scale irrigation due to a number of reasons. The principal factors led to this choice is, irrigation increases the potential for producing more food consistently in the drought-prone and food-insecure areas (Catterson et al 1999). But number of problems and constraints are faced with small scale irrigation system of the country. Limited knowledge in modern irrigation management (irrigation scheduling techniques, water saving irrigation technologies, water measurement techniques and operation and maintenance of irrigation facilities); inadequate knowledge on improved and diversified irrigation agronomic practices and low level of awareness of users about irrigated agriculture are the dominant ones (Yalew et al 2011).

Improving small scale farmers need to have efficient utilization of irrigation water (Shuhuai et al 2012). Agronomic practices have profound effect on farm water management practices. A number of factors such as nature of cultivar, plant density, sowing time, and nutrient and water management are involved in affecting profitable yield (Masoud and Ghodratolah 2010). Plant needs specific spacing to gain the limited irrigation water. Hence, varying plant spacing affects productivity and water use efficiency. Therefore, it is very important that those who work in irrigation agriculture understand clearly not only the benefits and consequence of irrigation but also what it takes to maximize or optimize the benefits out of it to contribute significantly in agricultural production growth.

Recently, interest has arisen in the effects of row spacing on maize grain yield and yield components. Decreasing the row spacing to less than 1 m has increased grain yields (Karlen and Camp 1985; Cardwell 1982). However, others studies also shows similar grain yield for row spacing of 38 and 76 cm (Westgate et al 1997). Sowing maize at row spacing less than 0.76 m may increase the maize's water use efficiency under limited water resource and better in controlling weeds as well (Forcella et al 1992). However, the yield responses to the possible interacting effects of furrow spacing and plant density (spacing between plants) is not known especially in the study area.

Maize is among the high water demanding crop throughout its growing stages of its physiological development. Maize is very sensitive to water stress but can attain its high yields when nutrients and water are optimally available in the soil (Traore et al 2000). The effects of water stress on maize not only reduce grain yield but reduces height of plants, diameter of shank, leaf area index and root growth (Wilson et al 2006). Many ways of conserving agricultural irrigation water have been investigated for different climatic and agro ecologic areas. Stone and Nofziger (1993) have used wide-spaced furrow irrigation or skipped crop rows as a means to improve irrigation water use efficiency (IWUE). They used as fixing some furrows for irrigation, while keeping adjacent furrows without irrigating throughout the growing season. Surface irrigation has been and still continues to be the widely used method of water application to agricultural lands. Design, evaluation and management of furrow irrigation, as one of the surface irrigation methods, rely on infiltration characteristics (Nasseri et al 2007).

In Southern zone of the Tigray Regional state, maize is often produced by furrow-irrigation under the limited water resource. Maize is the most competent for irrigation water with horticultural crops in the Raya Alamata district. Hence agronomic practices that can improve irrigation water productivity of small scale farmers is important for the area. This study investigated the effect of different furrow and plant spacing combinations on yield, yield components and irrigation water use efficiency of maize in order to provide theoretical basis for drought resistant and water saving planting methods under the specific soil and environmental conditions of the study area.

Materials and Methods

Description of study area

A field experiment was carried out in 2013, at Tumuga site located in Raya Alamata district of southern zone of Tigray regional state (Fig 1). This site is the basic representative for the lowland irrigation schemes of southern zone of Tigray regional state. It is located at 12^{o} 5' 25.47'' to 12 ^{o} 20' 7.06" N latitude and 39^{o} 31' 21.79" to 39 ^{o} 37' 41.59" E longitudes with an altitude of 1432 m a.s.l. The minimum and maximum monthly average temperatures are 14.2^{0}C to 29.8 ^{0}C, respectively, for 1997 to 2011 reference years. The average rainfall is around 700 mm (1997 – 2012 reference years). The site has limited irrigation water that cover a large hectare of farmland in which maize is the dominant crop grown in the command area followed by different horticultural crops. Farmers growing maize in the study area have not been practicing any specific plant and furrow spacings.

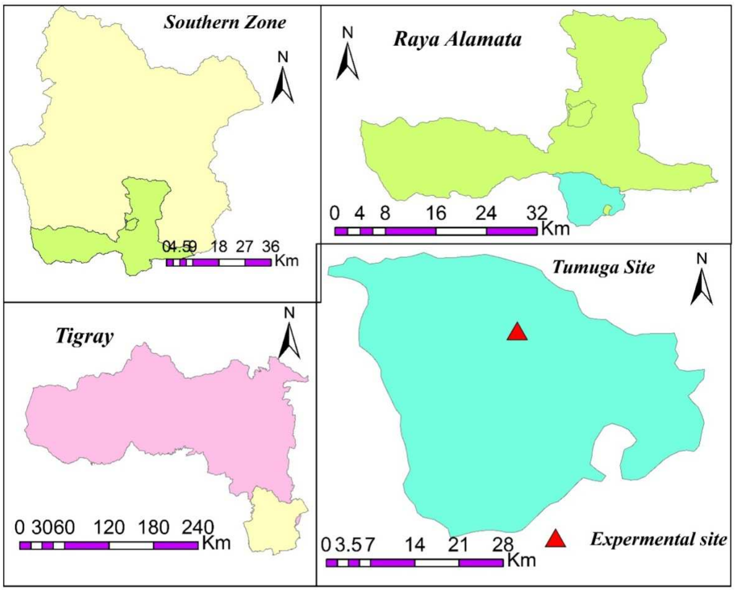

Figure 1. Location map of the experimental site

Experimental design and management

The experiment was laid out in a factorial randomized complete block design (RCBD) with nine treatments, namely, three levels of furrow spacing (50, 70 and 90 cm) and three levels of plant spacing (20, 25 and 30 cm) replicated three times with plot size of 4 m x 4 m. The distance between replication and plots were 2 m and 1 m, respectively. The plots in each replication were represented randomly for each treatment. Urea and Diammonium phosphate (DAP) were applied at rates of 300 kg ha^{-1} and 150 kg ha^{-1} as basal to all plots, respectively. Diammonium phosphate was applied at basal at planting but urea was applied both during planting and three weeks after planting (1/3rd at basal and 2/3rd three weeks after planting). The experimental plot was ploughed three times before planting and managed carefully from weeds to minimize water and nutrient competition with crop. BH543 maize hybrid was used as experimental crop.

The amount of water applied (estimated crop water requirement of maize for the specific site) throughout the growing season was equal to all treatments. Maize water requirement for the specific site was estimated using CROPWAT 8.0 software. Secondary data like meteorological data (monthly average temperature, relative humidity, sunshine hours, rainfall and wind speed) which are inputs for crop water requirement estimation was taken from the nearby meteorological station (Chercher meteorological station). Crop parameters (Kc values, rooting depth, yield response factor to water stress and other related data) was taken from FAO publications (Andreas and Karen 2002). Irrigation scheduling (irrigation interval and irrigation depth) of the experiment was estimated based on estimated crop water requirement of maize and soil characteristics.

Data measurements and analysis

As method of irrigation was furrow irrigation, the water applied per each irrigation event was measured using two inch par-shall flumes. Watering was done per fixed irrigation interval of seven days for each respective depth of water required throughout the growing season. The central rows of the plots were used for harvesting of biomass and grain yield measurement.

Irrigation water-use efficiency was calculated as the ratio of grain yield to the total water use (Michael 1978) as:

$$IWUE = \frac{GY}{W_{ap}}$$

Where: IWUE: Irrigation water use efficiency in fraction (kg m^{-3}), G.Y: Grain yield (kg/ ha^{-1}) and Wap: Amount of water applied (m^3/ha^{-1})

Collected data were statistically analyzed by GenStat 12th edition. Separate analyses were performed for each data. Treatment means were compared using least significant difference test ($\alpha = 0.05$) (Gomez and Gomez, 1984).

Results and Discussion

The results revealed that the differences between various levels of furrow and plant spacing were notable for grain yield, biomass yield, plant height, number of cobs per plant and irrigation water use efficiency (IWUE). More effects were observed on grain yield and IWUE of maize.

Estimation of crop water requirement

The applied amount of irrigation water for maize for the experimental site was estimated using CROPWAT 8 capabilities. The estimated gross irrigation water required was 642 mm under the assumption of furrow irrigation is 75% efficient. This estimation of irrigation water requirement of maize was conducted based on a ten (10) year meteorological data (2002-2011). Irrigation scheduling of the experiment was then developed as shown in Figure 2.

Grain and biomass yield of maize

Furrow spacing, as a main effect, and the interaction of furrow and plant spacing significantly affected grain yield but plant spacing had no significant effec The 50 cm furrow spacing gave significantly highest grain yields (4698 kg ha^{-1}), almost twice than that obtained under 90 cm furrow spacing (2684 kg ha^{-1}). Even though the level of plant spacing didn't show significant difference the highest yield (3791 kg ha^{-1}) was obtained under 20 cm plant spacing (Table 1).

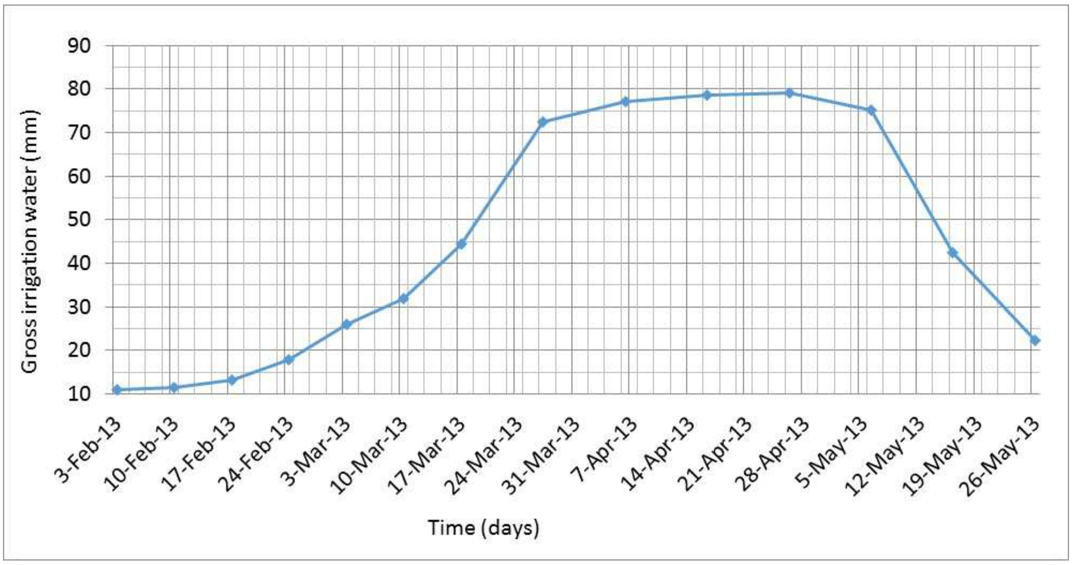

Figure 2. Temporal variation of Gross irrigation requirement throughout the growing season

The interaction furrow and plant spacing showed significant effect on grain yield i.e. 50 cm furrow with 25 cm plant spacing gave maximum yield of 5626 kg ha^{-1}(Table 2). Comparatively this furrow spacing might have supplied enough water to the crop and the higher plant density might have produced more grain yield than lower plant density. Least grain yields were scored when wider plant spacing (30 cm) was combined with larger furrow spacing (90 cm). This could be due to the fact tha large area of the plot was left blank and henceapplied water and nutrients are wasted. But onsiderable amount of yield (3687 kg ha^{-1}) was obtained from the larger furrow spacing (90 cm) combined with the smaller plant spacing (20 cm). In this case the larger furrow spacing effect might have been offset by smallest plant population that gave high yield because of availability of nutrients.

Table 1. Main effects of furrow and plant spacing on mean grain yield

Plant spacing (cm)	Grain yield (kg ha^{-1})	Furrow spacing (cm)	Grain yield (kg ha^{-1})
20	3791	50	4698^{a}
30	3581	70	3213^{b}
25	3223	90	2684^{b}
LSD	570	LSD	570
CV (%)	16.1	CV (%)	16.1

Means within columns followed by different letters differ significantly at P = 0.05

Table 2. Mean Grain and biomass yield for plant and furrow spacing interactions.

Furrow spacing , plant spacing	Grain yield (kg ha^{-1})	Furrow spacing , plant spacing	Biomass yield (kg ha^{-1})
50 , 30	5626^{a}	50 , 20	25060^{a}
50 , 20	4784^{a}	50 , 30	20560^{ab}
90 , 20	3687^{b}	50 , 25	18250^{abc}
70 , 25	3684^{b}	70 , 20	17170^{bc}
50 , 25	3334^{bc}	70 , 25	16440^{bc}
70 , 20	3256^{bc}	70 , 30	13980^{bc}
70 , 30	2696^{bc}	90 , 30	12190^{c}
90 , 25	2422^{c}	90 , 25	120.0^{c}
90 , 30	2298^{c}	90 , 20	11900^{c}
LSD	981	LSD	68..0.67

Levels not connected by the same letters are significantly different at P = 0.05.

For the study as a whole, the maximum biomass yield (25060 kg ha^{-1}), which was greater than 50% as compared to the minimum yield (11900 kg ha^{-1}) was obtained for the combination of (50, 20) and (90, 20) of furrow and plant spacing, respectively (Table 2). This show the dense plant populations which were about 20% greater at 20 cm plant spacing may contribute to a maximum biomass yield without significantly responding to grain yield.

Plant height and number of cobs per plant of maize

Both the interaction of furrow spacing with plant spacing and main effect of the two factors did not significantly affect plant height and number of cobs per plant of maize (Table 3). Comparatively longest plants (1.78 m) and highest of cobs per plant (1.58) were recorded from the 90 cm furrow + 30 cm plant spacing. This same combination was the third from the bottom that gives minimum yield of biomass and grain yield. While the shortest maize plants were recorded from 70 cm furrow combined with 30 cm plant spacing and the 70 cm furrow + 20 cm plant spacing interaction gave least number of cobs per plant (1.25).

Table 3. Interaction effect of treatments on plant height and number of cobs per plant.

Furrow spacing, plant spacing	Plant Height (m)	Furrow spacing, plant spacing	Number of cobs per plant
50 , 25	1.797	90 , 30	1.583
90 , 30	1.837	50 , 25	1.500
70 , 25	1.873	70 , 25	1.500
50 , 30	1.89	90 , 20	1.417
70 , 20	1.907	50 , 30	1.333
50 , 20	1.937	70 , 30	1.333
90 , 25	1.98	50 , 20	1.333
90 , 20	1.983	90 , 25	1.331
70 , 30	1.987	70 , 20	1.250
LSD	ns	LSD	ns
CV (%)	7.2	CV (%)	15.4

Irrigation water use efficiency

The IWUE values give a complete analysis of water resource use so that government regulators and conservationist knows how to influence farmers in the selection of the application of agronomic practice they use and the irrigation management system they apply when making irrigation decisions. It is very important to shift from maximizing productivity per unit of land area to maximizing productivity per unit of water consumed under limited irrigation water resource. This approach was used in calculating the IWUE. Hence, grain yield per amount of water applied is the major output of interest to the farmers. It is therefore the most important measure used to estimate the IWUE, which is expressed as yield in kg per m^3 of irrigation water used. Analysis of the IWUE results gave a significant difference for furrow spacing and for interaction of furrow and plant spacing. But there was no significant difference for the main effect of plant spacing levels (Table 4 and Table 5).

Table 4. IWUEs of Maize against main effects of plant and furrow spacing

Furrow spacing (cm)	IWUE (kg m^{-3})	Plant spacing (cm)	IWUE (kg m^{-3})
50	0.7317^{a}	20	0.5905
70	0.5004^{b}	30	0.5578
90	0.4181^{b}	25	0.5020
LSD	0.0887	LSD	0.0887
CV (%)	16.1	CV (%)	16.1

Means within columns followed by different letters differ significantly at α = 0.05

Table 5. IWUEs of Maize against the different plant and furrow spacing interaction

Furrow spacing , plant spacing	IWUE (kg m^{-3})
50 , 30	0.8763^{a}
50 , 20	0.7451^{a}
70 , 25	0.5744^{b}
50 , 25	0.5738^{b}
90 , 20	0.5193^{bc}
70 , 20	0.5071^{bc}
70 , 30	0.4199^{bc}
90 , 30	0.3772^{c}
90 , 25	0.3579^{c}
LSD	0.1537
CV (%)	16.1

Means within columns followed by different letters differ significantly at P = 0.05

The result presented in Table 5 revealed that irrigation water use efficiencies (IWUE) varied from 0.357 to 0.876 kg m^{-3}. The highest value of irrigation water use efficiency (0.876 kg m^{-3}) were under a combination 50 cm furrow and 30 cm plant spacing, while least IWUE (0. 357 kg m^{-3}) was obtained for 90 cm furrow spacing with 25 cm plant spacing combinations. The implication of this result is that resuming irrigation practices of maize at different furrow and plant spacing will have an adverse effect on the efficient utilization of the limited irrigation water. Even though the amount of water applied were the same for all treatments (620 mm), as the space between the furrow and plant spacing becomes wide, the dry biological yield (grain and biomass yields) might be affected by water stress due to inefficient water distribution efficiency around the root zone of the maize, evaporation and deep percolation which reduces irrigation water use efficiency of the maize crop (Table 5).

Conclusion and Recommendation

Irrigation water requirement of plants and its efficient utilization can vary from location to location depending on different factors such as soil, farmers practice and other agro-ecologies. For sustainable production of crops with sustainable and efficient utilization of limited water resource in a particular area, specific furrow and plant spacing recommendation is very crucial. From the field experiment, we could concludethat 642 mm depth of water was more productive in grain yield (5626 kg ha^{-1}) when using a combination of 70 cm furrow and 30 plant spacing. But in terms of biomass productivity the 642 mm applied irrigation water gives maximum yield (25060 kg ha^{-1}) using 70 cm furrow and 20 cm plant spacing. Larger production of grain yield and biomass yield were obtained using similar furrow spacing (70 cm) and the differences were in plant spacing where 30 cm plant spacing was for grain yield while 20 cm biomass yield. Hence small scale farmers of the study area could select one of the combinations depending on their interest to produce maize either for grain yield and livestock feed. The IWUE of this study ranged from 0.357 kg m^{-3} (90, 25 cm) (furrow spacing, plant spacing) to 0.876 kg m^{-3} (50 cm, 30 cm) (furrow spacing, plant spacing). Irrigation agronomists and development agents of the study area must create awareness to the small scale farmers to use 50 cm furrow spacing with 30 cm plant spacing in maize production.

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3. Livestock Technologies

3.1. Evaluation of *Sesbania macrantha* Genotypes as Animal Feed in the Lowland and Midland Areas of Northwestern Tigray, Ethiopia

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Abstract
The study was conducted to evaluate the performance of different *sesbania macrantha* genotypes for their forage production potential for animal feed. It was conducted at northwestern Tigray, northern Ethiopia where the districts namely Tselemti, Tahtay-kraro and Laelay-adyabo were selected purposively to represent the study area. Five *sesbania macrantha* genotypes called SM 0064, SM 0347, SM 0342, SM 0449 and DZ 0092 as standard check were used for the tial. Data on date of emergence, vigour, days to 50% flowering, plant height, branching ability, leaf to stem ratio, dry matter yield and chemical composition of the genotypes were collected. Data was analyzed using two ways ANOVA considering treatment (genotype) and location as independent factors. Chemical composition of the collected sample was analyzed using descriptive statistics. SM 0449 and SM 0342 had significantly ($p<0.05$) shortest germination dates at Tahtay-koraro, but at Tselemti and Laelay-adyabo the genotypes had similar germination date. The vigour of the genotypes at 50% flowering stage was similar at Tselemti and Tahtay-koraro but, SM 0342 and SM 0347 were significantly ($p<0.05$) highest at Laelay-adyabo. SM 0342 SM 0342 was earlier ($p<0.05$) to reach 50% of flowering stage (141 days) at Tselemti, but the result was similar at Tahtay-koraro and Laelay-adyabo except SM 0449 that was late to mature at Tahtay-koraro. Regarding to plant height SM 0342, DZ 0092 and SM 0064 at Tselemti, SM 0347 at Tahtay-koraro, SM 0347and SM 0342 at Laelay-adyabo were significantly ($p<0.05$) tallest compared to the other genotypes. The number of branches per plant of SM 0342 was significantly higher ($p<0.05$) at Tselemti (21.5) and Laelay-adyabo (23.83), whereas, similar with SM 0347 and higher than others at Tahtay-koraro (20.67). Ratio of leaf to stem of SM 0449 was higher ($p<0.05$) followed by SM 0342 at all tasting locations. Total dry matter forage yield of SM 0342 and SM 0347 was significantly higher ($p<0.05$) at Tselemti and Tahtay-koraro respectively, but both genotypes had similar yield result at Laelay-adyabo. Generally, the genotypes had similar nutritional composition, but concerning to crude protein content SM 0342 (20.32), SM 0347 (20.21) and SM 0064 (21.52) had relatively higher content relative to DZ 0092 (standard check) and SM 0449. Based on the evaluation result SM 0342 at Tselemti and Laelay-adyabo and SM 0347 at Tahtay-koraro were performed well and recommended to the respective districts and areas with similar agro-ecologies to help in solving feed shortage.

Keywords: Crude protein, dry matter, germination date, plant height, vigour.

Introduction

Livestock production is an important sector for the smallholder farmers of Ethiopia which contributes for food, income, organic manure and other services (Gizaw et al 2013). Ethiopia as well as Tigray region is endowed with huge ruminant population which can be estimated up to 116 million and 10 million respectively (CSA 2016), although their contribution is very limited to their producers. Feed scarcity in terms of quantity and quality is among the main obstacles mentioned repeatedly for increasing livestock productivity (Adane and Girma 2008, Yayneshet 2010). The common ruminant feed types in most parts of Ethiopia are natural pasture and crop residues which comprise about 55.3 and 31.3 percent respectively (CSA 2016). These feed types are characterized by their bulkiness and poor quality due to high concentration of lignin and low protein and energy content (Keftasa 1987, Aregheore 2000). Natural pastures have relatively low proportion of legumes which are known as protein sources to the animals (Yihalem et al 2006) and cannot support the maintenance level of animals especially during the dry season (Zinash et al 1995). In addition, the availability and type of these feed resources are dependent on altitude of an area, farming system, type of crop produced, intensity of cultivation and season (Williams et al 1997, Alemayehu 2008, Hassen et al 2010). Sesbania one of the multipurpose and drought tolerant trees uses for forage production, efficient nitrogen fixation (Mengistu et al 2002), fuel wood, and soil and water conservation. Kwesiga et al (1999) indicated the greater contribution of sesbania in improving the yield of maize even without applying mineral fertilizers.

Sesbania macrantha is one of the sesbania species which is described as fast to emerge with rapid growth rate (Mengistu et al 2002) and higher biomass yield than other species of sesbania with relatively higher nutritional value and digestibility (Mgangamundo et al 1999, Mengistu et al 2002). In addition, this species is suitable for improving fallows because of its higher branch and leaf it produces (Mgangamundo et al 1999). Therefore, introduction and evaluation of different *sesbania macrantha* genotypes in the area can help to increase quantity and quality of animal feed, and improving ruminant productivity. The objective of the study was to select the most adaptive and best performing sesbania genotypes in the area.

Materials and Methods

Study area description

The study was conducted at northwestern Tigray which contains six districts, namely, Medebay-zana, Tahtay-koraro, Asgede-tsimbla, Tselemti, Laelay-adyabo and Tahtay-adyabo. Three of the districts (Tselemti, Laelay-adyabo and Tahtay-koraro) were randomly selected for the study. Tahtay-koraro is located in 14^0 6' north latitude and 38^0 17' east longitude, and the dominant soil types of the district is sand-silt, silt-clay and clay. Tselemti is located at 13^o 05'north latitude and 38^o 08'east longitude. Nitosols, Cambisols and Vertisols are the most dominant soil types of the district. Tselemti, Laelay-adyabo and Tahtay-koraro are found at an elevation of 1300 and 1800 meter above sea level, respectively.

The administrative zone is endowed with a total ruminant population of 3.9 million (CSA 2016). The primary feed resources of northwestern Tigray where the study districts are found are crop residues, natural pasture and hay (Yayneshet 2010). Crops like sorghum, maize, finger millet, *teff* and rice are commonly grown crops at the study districts during the rainy season. The study was conducted between 2015 and 2016 cropping seasons.

Experimental design and data collection

The trial was conducted using randomized complete block design with three replications and five *sesbania macrantha* genotypes (*sesbania macrantha* 0064, *sesbania macrantha* 0449, *sesbania macrantha* 0342, *sesbania macrantha* 0347 and *sesbania macrantha* 0092 (as standard check)) in a 20 m^2 plot size. The plots were divided in to four rows with 1 m inter row spacing and seeds were sowed with 0.5 m spacing. The measurements taken during the study were germination days (the number of days between sowing and emerging date), vigor (the performance of the plants in a plot at 50% of flowering stage graded from 1-5, 5 given to the best performed), maturity days (the number of days between sowing and 50% of flowering stage), plant height (the height of the plant from the base to the tip of the plant in centimeter at 50% of flowering stage), branching ability (number of branches per plant), dry biomass (the total weight of sun dried forage yield harvested at 50% of flowering stage in kg/plot and converted to ton/ha), leaf to ratio (the ratio of leaf to stem of dried forage).

Chemical composition

Sesbania samples were taken from the leaf and edible stem part of the plant. Each sample was dried at 60°C for 72 hours and grinded to size that passes through 1 mm sieve. The ground samples were analyzed for DM, Ash, and N according the procedures of Association of Official Analytical Chemists (AOAC 1985). In-vitro dry matter digestibility (IVDMD) was estimated by procedures of Tilley and Terry (1964). Neutral detergent (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were also estimated based on the procedures indicated at Van Soest and Robertson (1985). Crude protein (CP), hemicellulose, and cellulose were estimated as follows.

OM % = 100- Ash %, and CP = N*6.25

Hemicellulose = % NDF - % ADF, and Cellulose = % ADF - % ADL

Statistical analysis

The collected data were analyzed using two ANOVA using statistical analysis software (SAS) to investigate the effect of accession across location and its interaction. Significantly different means were separated using least significance difference at 95% confidence level.

Result and Discussion

Growth performance

The germination ability and growth performance of *sesbania macrantha* genotypes are presented in Table 1. The Genotypes differed significantly ($p<0.05$) in their germination dates at Tahtay-koraro where SM 0449 and SM 0342 had shortest germination dates compared to the other genotypes unlike to Tselemti and Laelay-adyabo which was similar for all genotypes. At Tahtay-koraro where that have relatively light soil compared to other two tasting locations, in general the genotypes have short germination dates. Similar to this result, (Mengistu et al 2002) reported the fast emergence ability and higher growth rate of *sesbania macrantha* species than other sesbania species of genotypes that helps the species to bear up the computation of weeds in light soils. Although, SM 0347 was late in germinating, the genotype reaches 50% flowering earlier, which supported it to be vigorous and taller than the other evaluated genotypes. The vigor and plant height of this genotype was still higher at the area which can be a good mirror for potential performance and forage yield.

The score given for the observed stand performance (vigour) of the genotypes at 50% flowering stage was similar at Tselemti and Tahtay-koraro but, SM 0342 and SM 0347 had significantly ($p<0.05$) highest score at Laelay-adyabo. The number of days to 50% flowering stage after sowing of the genotypes were found different ($p<0.05$). According to the result, SM 0342 was earlier to reach 50% of flowering (141 days) at Tselemti. The genotypes had similar number of days to 50% of flowering at Tahtay-koraro and Laelay-adyabo except SM 0449 that was late to mature at Tahtay-koraro. Considering locations the genotypes required shorter number of days from sowing to forage harvest (50 % of flowering) at Tahtay-koraro (117 days) followed by Tselemti (146.3 days) and Laelay-adyabo (144.8 days). Regarding the height of the genotypes SM 0342, DZ 0092 and SM 0064 at Tselemti, SM 0347 at Tahtay-koraro, SM 0347 and SM 0342 at Laelay-adyabo were significantly ($p<0.05$) highest compared to the other genotypes.

Branching ability and dry matter yield

Branching ability, leaf to stem ratio and total dry matter yield of *sesbania macrantha* genotypes are presented in Table 1. The number of branches per plant (branching ability) of SM 0342 was significantly higher ($p<0.05$) than the other evaluated genotypes at Tselemti (21.5) and Laelay-adyabo (23.83), whereas, similar with result of SM 0347 at Tahtay-koraro (20.67). This higher number of branches per plant of SM 0342 can be a good indicator for forage production potential of the genotype as supported by the report of (Mgangamundo et al 1999) who stated the suitability of *Sesbania macrantha* for supplying quality fodder during dry season, improved fallows and relay cropping systems because of greater branch and leaf biomass production.

The ratio of leaf to stem of SM 0449 was higher (p<0.05) than the other genotypes at all tasting locations followed by SM 0342. Total dry matter biomass yield of SM 0342 and SM 0347 was significantly higher (p<0.05) at Tselemti and Tahtay-koraro compared to the tasted genotypes respectively, unlike to Laelay-adyabo that was obtained similar yield result from SM 0342 and SM 0347.

Table 1. Day to emergence, vigour and Day of 50% flowering of *sesbania macrantha* genotype sown across the three sites

Treatments/genotypes	Parameters (mean ± S.E.)			
	Days to emergence	Vigour	Days to 50% flowering	Plant height
Tselemti				
SM 0449	14.67ab ±0.33	18.7b ±0.42	153.7a ±0.56	192.8b ±1.92
SM 0342	15.33a ±0.42	21.5a ±0.22	141c ±0.52	204.2a ±2.6
DZ 0092	14.67ab ±0.42	18.7b ±0.21	145.5bc ±1.34	202.5a ±2.17
SM 0064	14.17b ±0.31	17.2c ±0.31	146b ±2.35	206.5a±1.96
SM 0347	15.67a ±0.21	21.7a ±0.49	146.5b ±2.09	192b ±2.63
Mean	14.9b±0.18	19.53 ±0.36	146.3a ± 1.0	199.6b ±1.46
CV	5.72	4.38	2.62	2.79
P-value	0.04	<.0001	0.00015	0.00015
Tahtay-koraro				
SM 0449	9.83d ±0.40	3.5b ±0.5	121.5a ±0.43	217.8c ±5.1
SM 0342	9.33d ±0.21	4.5ab ±0.34	115ab ±2.73	226.2c ±5.38
DZ 0092	12.5b ±0.22	4ab ±0.37	116.2b ±2.55	221.7c ±2.8
SM 0064	15.17a ±0.48	3.83ab±0.31	115.5b ±1.77	237.3b ±1.41
SM 0347	11.33c ±0.33	4.67a ±0.33	117b ±0.97	249.2a ±1.66
Mean	11.63c ± 0.41	4.10a ± 0.18	117b ± 0.87	230.4a ±2.61
CV	7.26	22.44	3.79	3.91
P-value	<.001	0.197	0.1158	<.0001
Laelay-adyabo				
SM 0449	16.33b ±0.42	2.83 ±0.31	148a ±2.18	178.3b ±2.17
SM 0342	17.67a ±0.21	2.67 ±0.33	146.7ab ±1.52	198.8a ±2.64
DZ 0092	16.83ab ±0.47	3.33 ±0.21	143.2b ±1.19	169c ±1.83
SM 0064	16.67ab ±0.21	3.33 ±0.21	143b ±0.577	166.5c ±1.43
SM 0347	17.33ab ±0.33	3 ±0.26	143.2b ±1.28	169c ±1.90
Mean	16.97a ± 017	3.03b ± 0.12	144.8a ± 0.72	176.3c ±2.37
CV	5.02	21.7	2.44	2.82
P-value	0.02	0.323	0.05546	<.0001

Means with the same letter in the same column are not significantly (P<0.05) different.

Table 2. Branching ability, leaf to stem ration and total dry matter yield of *sesbania macrantha* genotype sown across the three sites.

Treatments/genotypes	Parameters (mean ± S.E.)		
	Branching ability	Leaf/stem ratio	Total dry matter yield
Tselemti			
SM 0449	19.8b ±0.42	0.624a ±0.014	4.97d ±0.04
SM 0342	21.5a ±0.22	0.598b ±0.018	7.14a ±0.04
DZ 0092	17.0c ±0.21	0.554c ±0.017	4.69e ±0.07
SM 0064	17.0c ±0.31	0.514d ±0.023	6.49c ±0.12
SM 0347	21.0a ±0.49	0.51d ±0.025	6.88b ±0.05
Mean	19.267 ±0.36	0.560 ±0.01	6.02a ±0.19
CV	3.93	2.05	2.89
P-value	<.0001	<.0001	<.0001
Tahtay-koraro			
SM 0449	20.3b ±0.58	0.624a ±0.043	4.63d ±0.149
SM 0342	22a ±0.6	0.607b ±0.023	6.35b ±0.036
DZ 0092	16d ±0.26	0.56c ±0.025	4.98c ±0.049
SM 0064	17c ±0.56	0.506d ±0.026	6.8a ±0.036
SM 0347	20.67b ±0.33	0.511d ±0.031	6.72a ±0.026
Mean	19.20 ±0.29	0.562 ±0.02	5.89a ±0.17
CV	3.989	2.51	3.11
P-value	<.0001	<.0001	<.0001
Laelay-adyabo			
SM 0449	21.17b ±0.42	0.623a ±0.030	4.83c ±0.06
SM 0342	23.83a ±0.58	0.605b ±0.019	6.47a ±0.13
DZ 0092	15.33d ±0.42	0.555c ±0.018	4.4d ±0.16
SM 0064	15.17d ±0.42	0.514d ±0.020	6.17a±0.17
SM 0347	19.83c ±0.48	0.512d ±0.015	6.41a ±0.14
Mean	19.067 ±0.99	0.562 ±0.02	5.65
CV	4.017	1.81	10.21
P-value	<.0001	<.0001	<.0001

Means with the same letter in the same column are not significantly (P<0.05) different.

Nutritional Composition

In general, the evaluated genotypes have similar nutritional composition Table (3). Considering their crude protein (CP) content SM 0342 (20.32), SM 0347 (20.21) and SM 0064 (21.52) had relatively higher content as compared to DZ 0092 (standard check) and SM 0449 which the suitability of the genotypes to the areas where the study was conducted. This CP content is in general within the range of protein specified as acceptable level (7.8-8%) for maintenance and production of ruminants (Vansoest 1982). According to Lonsade (1989), feeds are classified as low, medium and high protein sources if they contain less than 12%, 12-20% and greater than 20% crude protein respectively. Therefore, SM genotypes SM-0449 and SM-0092 are classified as medium protein sources whereas SM-0342, SM-0064 and SM-0347 can be considered as high protein source feeds. In general the feed types obtained from these genotypes are also considered as supplemental feeds, which can be used as potential supplement feeds for grass hay and crop residue based feeding systems. In addition, the standard check had relatively higher acid detergent fiber (33.41) than the other evaluated genotypes. The In-vitro dry organic matter digestibility (IVDOMD) of SM 0342 (58.61) and SM 0347 (57.17) was relatively higher than the other genotypes.

Table 3. Chemical composition of *sesbania macrantha* genotypes

Accession	Chemical composition (%)									
	DM	Ash	OM	CP	NDF	ADF	Hemi-cellulose	Cellulose	ADL	IVDOMD
SM0449	93.74	7.47	93.53	18.74	37.64	22.70	14.94	7.31	15.39	54.45
DZ0092	93.45	7.67	92.33	17.91	42.97	33.41	9.56	15.34	18.07	54.59
SM0342	93.98	7.60	92.40	20.32	38.55	27.79	10.76	10.99	16.80	58.61
SM0347	93.95	7.07	92.93	20.21	33.45	24.25	9.20	8.55	15.70	57.17
SM0064	94.08	6.99	93.01	21.52	38.27	23.27	15.00	10.81	12.46	54.59

Conclusion and Recommendation

The study was conducted to evaluate forage production potential of different *Sesbania macrantha* genotypes at northwestern Tigray. The genotypes used were *Sesbania macrantha* 0064, *Sesbania macrantha* 0449, *Sesbania macrantha* 0342, *Sesbania macrantha* 0347 and *Sesbania macrantha* 0092 (as standard check) using RCB design in a 20 m^2 plot size at three locations for two years. Data on number of germination days, vigor, maturity days, plant height, number of branches per plant, dry biomass, leaf to ratio and nutritional composition were recorded. SM 0449 and SM 0342 was earlier to germinate at Tahtay-koraro, but the germination date of all genotypes was similar at Tselemti and Laelay-adyabo. The score given for vigour of the genotypes was similar for all genotypes at Tselemti and Tahtay-koraro but, SM 0342 and SM 0347 were highest than others at Laelay-adyabo. SM 0342 was fast to reach 50% flowering stage that required 141 days and gave an opportunity for selecting the genotype to Tselemti district. Regarding to Tahtay-koraro and Laelay-adyabo almost all evaluated accessions required similar number of days to 50% flowering stage from sowing date. Plant height of SM 0342, DZ 0092 and SM 0064 at Tselemti, SM 0347 at Tahtay-koraro, and SM 0347 and SM 0342 at Laelay-adyabo during harvesting stage (50% flowering) was higher, that showed the potential of producing higher forage yield for their respective districts. According to the evaluation trial conducted result of number of branches per plant for SM 0342 was higher at all tasting locations, except with its similarity at Tahtay-koraro with SM 0347. The ratio of leaf to stem of SM 0449 was higher at all districts included in the study succeed by SM 0342. Total dry forage yield of SM 0342 and SM 0347 was super to other genotypes at Tselemti and Tahtay-koraro respectively, with similar yield at Laelay-adyabo. The evaluated genotypes had generally nutritional composition and in-vitro digestibility, but considering their crude protein content SM 0342 (20.32), SM 0347 (20.21) and SM 0064 (21.52) had relatively higher content as compared to DZ 0092 (standard check) and SM 0449. Therefore, based on the obtained result and observed performance SM 0342 at Tselemti and Laelay-adyabo, and SM 0347 at Tahtay-koraro were performed well and recommended to the districts and areas with similar agro-ecologies to help in solving ruminant feed shortage.

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3.2. Verification of Indigenous Forage Grass Genotypes for Growth and Yield Performance in Western Lowlands of Tigray, Ethiopia

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Abstract

The study was carried out to verify the growth and yield performances of two local grass genotypes under rain fed conditions of Kafta Humera and Tsegede districts of western zone of Tigray, Ethiopia, specifically in three locations namely humera, Kebabo and banat, and one on station and three on farms per a location. Mezrut (*Echinochloa Spp*) and Mechello (*Aethiopicum Spp*) were the local grasses and Rhodes grass was used as standard Check. Broadcasting was the planting method used for sowing each grass in a plot area of 10m*10m. Days to emergence, days to 50% flowering and maturity, Dry forage biomass and seed yields were the forage attributes used for evaluation of the grass genotypes at field level in addition to laboratory nutritional analysis parameters. Both Mezrut (*Echinochloa Spp*) and Mechello (*Aethiopicum Spp*) yielded significance higher forage biomass and seed yields, mature and reach to 50% flowering earlier than the standard check across the tested locations. The Crude protein content of Mezrut (13.88%CP) is higher than the Crude protein content of Rhodes grass (9.3% CP) and Mechello grass (8.76%CP) at 50% flowering. The Crude content of Mechello grass at onset of flowering (13.56%CP) is higher while its lignin content (5.59%) is lower. The recommended harvesting stage for quality hay of Mezrut grass is 50% flowering while onset of flowering is the appropriate harvesting stage for quality hay of Mechello grass. The National Variety Releasing Committee (NVRC) visited the local grasses by the technical committee in all locations and on-farms at stage of 50% flowering. After a thoroughly evaluations, the NVRC decided to release both local grasses. Therefore, both Mezrut (*Echinochloa Spp*) and Mechello (Aethiopicum Spp) are the best promising local grass forages with high feeding values over the standard check and they are recommended to lowland moisture stressed areas of Tigray as well as other similar ecologies of Ethiopia. Further works should be conducted in demonstration and popularization as well as to scale up/out these grass forages to wider areas with several primary farmers so as to enhance adoption and efficient utilization of the grasses.

Keywords: Kafta Humera, Mezrut, Mechello, Rhodes, Tsegede

Introduction

The quantity and quality of feed resources are the most important factors that determine livestock productivity (Yaynshet 2010). Scarcity of feed is one of the major constraints hampering market-oriented livestock production (Firew and Getnet 2010). In countries with populated human population, natural grazing lands are continually decreasing because they are converted to crop cultivation to satisfy the needs of increasing human population. Livestock are, therefore, forced to graze on unconventional fields such as marginal lands, road sides, river bank, plantation areas, etc. (Muhammad 2014). On the other hand, most of the roughage found in the tropics is generally deficient in nitrogen, energy or some minerals. Therefore, they cannot adequately support growth and milk production in ruminants (Ash 1990; Gray and Gupta 1992). The quality and quantity of forage available from natural pasture is diminishing due to excessive grazing pressure.

In Western zone of Tigray, Ethiopia, there are different local grasses and legume livestock forage species that could alleviate the current feed scarcity and need to manage in arable land and used as livestock feeds. Local grass is among the common feed resources in the area. Despite the presence of different species of local grasses, their biomass yield and nutritional value were not known. In addition to this, proper agronomic practice is important, for example, application of fertilizer to increase dry matter yield and nutritive value have been suggested to be one method to improve animal production in developing countries (Peyard and Astigarraga 1998). But the high price of commercial fertilizer makes it unaffordable for most subsistence farmers. Moreover, there is vast area of rangeland in Western Tigray that endowed with a number of grass forage species that can serve as potential livestock feed. However, they have not been efficiently exploited yet due to lack of awareness of farmers towards when and how they can harvest and feed for their animals. Such lack of information and awareness made their contribution as livestock feed to remain low. Taking this situation into consideration, Humera Agricultural Research Center has screened and conducted research for three years and identified high yielding and palatable local grasses with high nutritive values. Therefore, the present study was initiated to verify the growth and yield performance of the screened high performing forage grass genotypes in farmers' management system, and to assess the perception of farmers regarding the forage grasses.

Materials and Methods

Description of the study area

The verification trial of local grasses was conducted in lowlands of Kafta Humera district (on station and on farm) and Tsegede district of Western zone of Tigray, Ethiopia (Figure 1). The districts are located in a distance in the range between 580-750 km from Mekelle, the capital city of Tigray region, Ethiopia. The zone covers an area of 1.5 million hectare with Kafta Humera accounts 48.13%; Setit Humera accounts 0.82%, Tsegede accounts 23.43% and Welkait accounts 27.62% (HuARC, Unpublished). The total cultivated land of the zone is 573,285 hectares (38.2%) while the uncultivated land accounts 927,000 hectares (62.8%). Of the total, 36.8% of the uncultivated land (341,195.25 hectare) is covered by different plant species excluding Boswellia and Acacia Senegal while 185,510 hectares (20%) of the unfarmed land is solely covered by both Boswellia and Acacia Senegal. The zone consists of three agro-ecological zones (lowland, midland & highland) in which kolla (lowland) represents 75%, weynadegga (midland) account for 15.7% and dega (highland) account for 9.3% of the land coverage of the zone.

The geographical location of the zone is 13°42′ to 14°28′ north latitude and 36°23′ to 37°31′ east longitude (Mekonnen *et al* 2011). The annual rainfall of the zone ranges from 600 mm to 1800 mm while the annual temperature ranges from 270c to 45 0c in the lowland areas (Kolla) and 100c to 22 0c in both midland and highland areas of the zone. The altitude of the zone ranges from 500- 3008 m.a.s.l. The zone shares borders with Tahtay Adibayo, Tselemti and Asgede Tsimbla in the East, Sudan in West, Amhara region in South and Eritrea in the North. The study area represents a remote, tropical climate where extensive agriculture is performed manually by large numbers of migrant laborers.

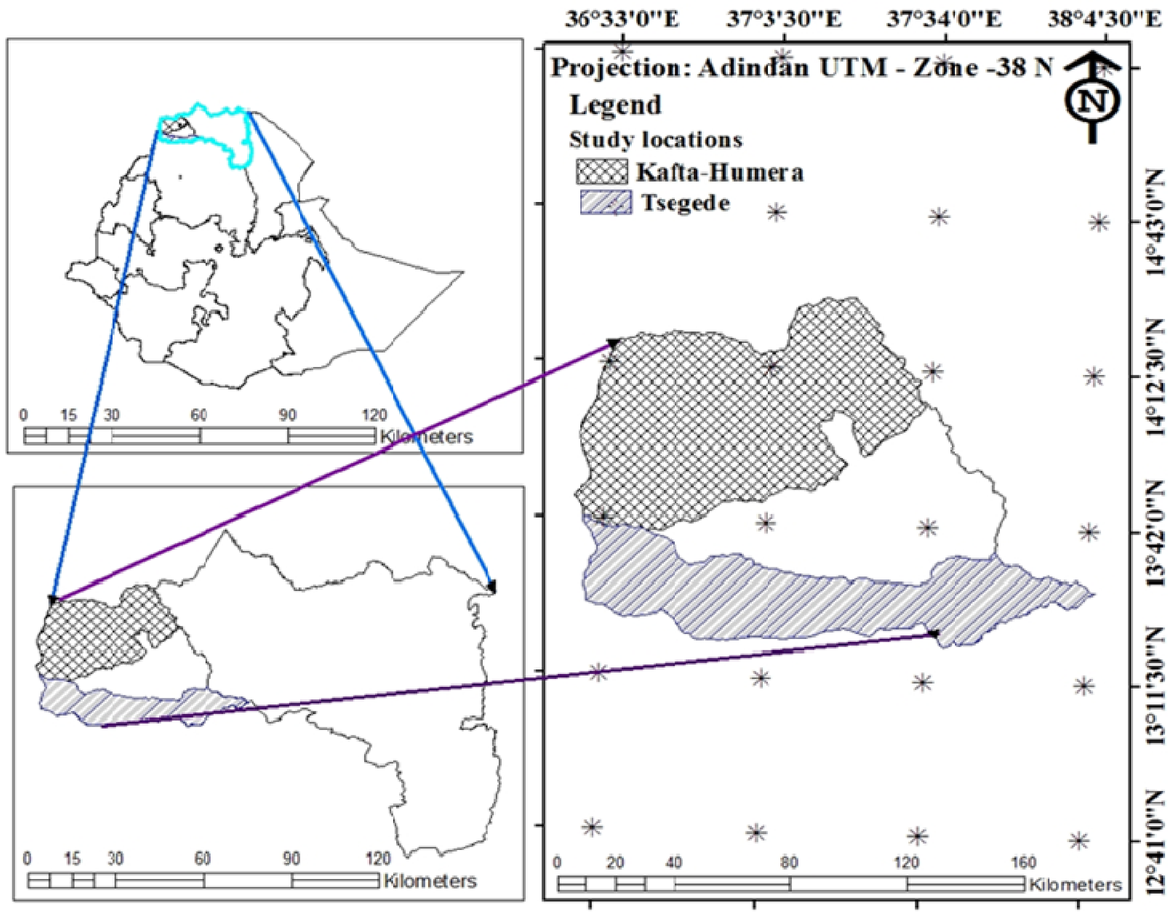

Figure 1: Location map of the study areas, Kafta Humera and Tsegede districts in western of Tigray region, northern Ethiopia

Planting method, treatments and design

The candidate local grass genotypes, Mezrut (*Echinochloa Spp*) and Mechello (*Aethiopicum Spp*) were the selected grass genotypes based on their high biomass yield and nutritional composition and Rhodes grass was obtained from Werer Agricultural Research Center used as standard check for the verification trial. Broadcasting was the planting method used for sowing each grass in a plot area of 10m*10m with a plot spacing of 3 meter apart. Grass seeds were sown at the onset of rainy season around early to mid June. The trial was laid out in a randomized complete block design with four replications by assuming the three farmers and one on station of each location were used as replication.

Data collected

Data to be collected includes days to emergence, days to 50% flowering, days to maturity, dry matter and seed yield, farmers perception as well as disease/pest incidence of the forage grass genotypes and were recorded. At 50% flowering stage, 1m x 1m quadrant size was used for dry matter yield determination. Grasses within a 1 m x 1m quadrant were harvested at the ground level and fresh biomass weighted immediately using a 0.1 g scale. Then, a sub-sample of 15-20% of the total weight was separated and put into a paper bag for dry matter yield determination. The sub-samples were oven dried at 105 0^c for 24 hours. At maturity stage, seed yield of the grass genotypes were determined by harvesting the seeds from the remaining portion of the plots by hand picking. Perceptions of farmers towards candidate local grasses were assessed through direct household interview while field evaluation.

Chemical analysis and in vitro dry matter digestibility

During the last experimental period, samples of the grass genotypes at three different flowering stages /onset, 50% and 100% flowering) were taken and dried. The dried samples were ground to pass through 1mm sieve for quality determination. Ground Samples were bulked on the basis of replicates and a sub sample of each was taken for analysis. Samples were ignited in a muffle furnace at 550°*C* (AOAC 1990) to determine ash contents of the grass genotypes. Crude protein (CP) was determined using Kjeldahl method (AOAC 1990). Van Soest et al (1991) procedure was used to determine Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and Acid Detergent Lignin (ADL). The In vitro dry organic Matter digestibility (IVDOMD) was determined according to the two stages method outlined by Tilley and Terry (1963). All chemical composition and IVDOMD analyses were carried out at Holetta Agricultural Research Center, Nutrition laboratory.

Data analysis

The collected data were analyzed by analysis of variance using general linear model procedure of SAS version 9.2 (SAS 2008). The Stastical model was:

$\mathbf{Y_{ijkl} = \mu + V_{i} + B_{j} + L_{k} + VL_{l} + E_{ijkl}}$, where,

Y_{ijKl} = the corresponding growth & Forage yield parameter

μ = the overall mean,

V_i = the fixed effect of i^{th} grass genotype (i= Mezrut, Mechello, Rhode grass)

B_j = the block effect,

L_k = the fixed effect of k^{th} study location (k= Humera, Banat and Kebabo)

TL_l = location * grass genotype interaction effect & E_{ijkl} = the random error

Differences among means with P<0.05 were accepted as representing statistically significant differences. Tukey multiple mean comparisons was employed to separate significant means.

Results

Days to emergence, 50% flowering and maturity

Days to emergence and 50% flowering obtained from the three grass genotypes sown in three locations are presented in Table 1. Grass genotypes significantly varied (P<0.05) in days to emergence and 50% flowering. Similarly, days to maturity were significantly among the three grass genotypes (Table 2). Both candidate local grass genotypes were earlier to emerge while the standard check (Rhodes grass) was the latest to emerge in the rain fed conditions of the three study locations. Likewise, both candidate local grass genotypes were earlier to reach days to 50% flowering and days to maturity.

Dry matter herbage and seed yield

Dry matter yield was significantly different (p<0.05) among the three grass genotypes in all study locations (Table 3). In all study locations, highest Dry biomass yield was obtained from Mezrut followed by Mechello while the least dry biomass yield was obtained from the standard check (Rhodes grass). Significant differences (P<0.05) were observed among the grass genotypes in seed yield across all the experimental locations. Seed yield varied between 5.34 and 20.9 quintal ha^{-1} with a mean of 15.3 quintal ha^{-1} over the genotypes in all study locations.

Table 1. Days to emergence and days to 50% flowering of the grass genotypes

Grass genotypes	Days to emergence (days)				Days to 50% flowering (days)			
	Humera	Banat	Kebabo	Mean	Humera	Banat	Kebabo	Mean
Mezrut	10.4±0.5[b]	9.8±1.0[b]	9.5±0.7[b]	9.8±0.4[b]	56.2±2.4[b]	56.1±1.9[b]	51.1±1.2[c]	54.5±1.4[c]
Mechello	10.9±0.5[b]	11.4±1.0[b]	10.8±0.7[b]	11±0.4[b]	73.7±2.4[a]	74.1±1.9[a]	65.1±1.2[b]	70.9±1.4[b]
Rhodes grass	20.5±0.5[a]	19.3±1.0[a]	20.5±0.7[a]	20.1±0.4[a]	77.2±2.4[a]	79.0±1.9[a]	83.0±1.2[a]	79.8±1.4[a]
Mean	13.9±0.4	13.5±0.4	13.6±0.4	13.7±0.3	69.0±1.1	69.8±1.1	66.4±1.1	68.4±0.6
CV (%)	7.72	14.05	10.6	11.04	6.84	5.6	3.62	6.9
P-value	0.0001	0.0001	0.0001	0.0001	0.0003	0.0001	0.0001	0.0001

Means with the same letter in the same column are not significantly ($p<0.05$) different

Table 2. Days to maturity of the grass genotypes

Grass genotypes	Days to maturity (Days)			
	Humera	Banat	Kebabo	Mean
Mezrut	80.8±2.0[b]	79.2±1.5[b]	87.7±0.5[b]	82.5±1.1[c]
Mechello	87.1±2.0[b]	84.3±1.5[b]	88.2±0.5[b]	86.6±1.1[b]
Rhodes grass	98.2±2.0[a]	97.2±1.5[a]	100.4±0.5[a]	98.6±1.1[a]
Mean	88.7±0.8	86.9±0.8	92.1±0.8	89.2±0.5
CV (%)	4.5	3.35	1.14	4.1
P-value	0.0001	0.0001	0.0001	0.0001

Means with the same letter in the same column are not significantly ($p<0.05$) different.

Table 3. Days to Maturity, herbage dry matter and seed yield of the grass genotypes

Grass genotypes	Dry matter yield (ton/ha)				Seed yield (quintal/ha)			
	Humera	Banat	Kebabo	Mean	Humera	Banat	Kebabo	Mean
Mezrut	23.2±0.3[a]	21.6±0.3[a]	22±0.2[a]	22.3±0.3[a]	20.2±0.7[a]	22±0.9[a]	20.7±0.4[a]	20.9±0.4[a]
Mechello	19±0.3[b]	17.8±0.3[b]	16.2±0.2[b]	17.7±0.3[b]	19.2±0.7[a]	18.6±0.9[a]	20.7±0.4[a]	19.5±0.4[b]
Rhodes grass	6.7±0.3[c]	6.3±0.3[c]	6.3±0.2[c]	6.4±0.3[c]	4.9±0.7[b]	5.5±0.9[b]	5.6±0.4[b]	5.34±0.4[c]
Mean	16.3±0.2	15.2±0.2	14.8±0.2	15.5±0.1	14.8±0.4	15.4±0.4	15.7±0.4	15.3±0.2
CV (%)	3.3	4.3	2.39	6.1	9.2	11.5	4.8	9.3
P-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

Means with the same letter in the same column are not significantly ($p<0.05$) different

Table 4. Nutritional quality (mean in %) of local grasses and the standard check

Sample Type	DM%	Ash %	OM%	NDF%	ADF%	Lignin %	CP%	IVDOMD%
Mechello								
On set of flowering	92.34	12.10	87.90	65	44.65	5.59	13.56	53.81
50%	94.09	10.21	89.79	70.21	48.29	8.08	8.76	50.74
100%	95.04	9.66	90.34	70.38	50.42	8.88	6.51	49.36
Mezrut								
On set of flowering	91.40	19.97	80.03	59.75	40.43	6.69	14.53	58.09
50%	91.59	16.29	83.71	64.55	42.29	7.28	13.88	57.16
100%	93.22	14.46	85.54	65.47	47.32	8.91	10.50	47.52
Rhodes grass								
50% flowering		10.6	-	70.6	36.7	4.4	9.3	65

Disease and pest occurrence

From field observations, different fungal, bacterial and viral diseases affect different parts of oil crops and legume forage crops at different growth stages. The disease observed in the study area was leaf spot (Xanthomonas axonopodis Pv.vignicola). The common pests observed during the experimental period were blister beteele (Lytta aenea) and aphid (Aphis craccivora). Blister beteele mostly damaged when the seedlings of legume forage and crops were at their flag leaf stage and aphid's invasion occurred during early maturing on flag shoots and immature green pods of legume forages and crops. Both local grasses had high tolerance against these mentioned diseases and pests.

Nutritional value

The nutritional quality analysis of the grass genotypes is presented in Table 4.The result of Nutritional quality analysis indicated that there are differences among the grass genotypes in Ash%, NDF%, ADF%, Lignin%, CP% and Invitro Dry Organic Matter digestibility (IVDOMD%). The Ash, Crude protein content and Invitro dry organic matter digestibility of both Mezrut and Mechello grass genotypes decrease while NDF%, ADF% and Lignin content of the grasses increase as maturity advances. The ash content of the grass genotypes varied from 12.10% (Mechello) to 19.97% (Mezrut) in the onset of flowering. Similarly, the highest ash content was obtained from Mezrut (16.29%) followed by Rhodes grass (10.6%) while the least content was determined from Mechello (10.12%) in 50% flowering. The Crude protein content of the grass genotypes ranged from 13.56% (Mechello) to 14.53% (Mezrut) in the onset of flowering. Likewise, highest crude protein was obtained from Mezrut (13.88%) followed by Rhodes grass (9.3%) while the minimum crude protein was attained from Mechello (8.76%).

As the nutritional analysis results indicated that both local grass genotypes are quality grass forages. The appropriate harvesting stage of Mezrut grass for quality hay is 50% flowering while onset of flowering is the proper harvesting stage of Mechello because its crude protein content decreases and it becomes more lignified as harvesting stage increases. They are suitable for improved forage production strategies in both irrigable and rain fed conditions of different environmental niches of western zone of Tigray like rehabilitation of degraded grazing lands, roadsides, marginal forage development and backyard forage establishment through direct over sowing. They are also used for contour forage strips strategies-for forage production and soil stabilization through reducing run off and thereby increases infiltration and reduce soil erosion. They are also used for permanent pasture forage strategy –for cut and carry feeding system. They can also be used for silage making.

Farmers' perception

Farmers used different forage production attributes for the evaluation of the grass genotypes during field observation (Table 5). The seed availability of both Mezrut and Mechello is higher than the planting material of the standard chick (Rhodes grass) as the seeds of local grass genotypes are available with any farmer of the study area. Farmers also tried to evaluate the animal preference and palatability of the three grass genotypes by harvesting green hay at the recommended harvesting stages of each grass and offering to their animals during the evaluation period. Mezrut and Mechello were found to be highly preferred by animals and palatable as compared to Rhodes grass. Farmers observed that feeding green hay of the three grass genotypes for their animals improve the body conditions of animals. During formal interviews, farmers said that animals fed on green hay form of Mezrut grass during rainy season have improved body conditions and never emaciated throughout the year.

Based on field observations and farmers' interview, both local grass genotypes (Mezrut and Mechello) had high score of resistance to prevailing diseases and pests like blister beetle and others than Rhodes grass. Moreover, both Mezrut and Mechello had a high score in moisture stress tolerance than Rhodes grass and hence more suitable for improved forage development strategies in moisture stress areas of western zone of Tigray. Farmers said that both Mezrut and Mechello grass genotypes had a medium score while Rhodes grass with low score of tolerance to weed infestation.

Table 5. Farmers' Perception on the local forage grasses as compared to the standard check

Attribute	Mezrut vs Rhodes grass		Mechello vs Rhodes	
	Mezrut	Rhodes	Mechello	Rhodes
Availability of Planting material				
✓ Available	x		x	
✓ Not Available		x		x
Animal preference				
✓ less preferred				
✓ Moderately preferred		x		x
✓ Highly Preferred	x		x (*)	
Palatability				
✓ Less palatable				
✓ Moderately Palatable		x		x
✓ Highly palatable	x		x (*)	
Animal feed on green hay				
✓ No change in body condition				
✓ Improved body condition		x	x	x
✓ Improved body condition	x			
Disease and Pests Resistance				
✓ High	x (**)		x (**)	
✓ Medium		x		x
✓ Low				
Tolerance to Dry season /moisture stress)				
✓ High	x		x	
✓ Medium		x		x
✓ Low				
Ease of Seed collection				
✓ Simple	x			
✓ Moderate		x	x	x
✓ Difficult				
Land preparation level for production				
✓ Intensive		x		x
✓ Moderate	x		x	
✓ Less				
Ease of forage production				
✓ Simple	x		x	
✓ Moderate				
✓ Difficult		x		x
Tolerance to weed infestation				
✓ High				
✓ Medium	x		x	
✓ Low		x		x

NB: * = Highly palatable at onset of flowering and **= both local grass genotypes are resistance to blister beetle and other pests.

During the formal interview, farmers said that the ease of forage production of both Mezrut and Mechello is simple as compared to Rhodes grass. Forage production with Rhodes grass requires intensive land preparation and weeding unlike to both Mezrut and Mechello grasses where they are planting in either well prepared land or boundaries and other uncultivable places without any Agronomic practices (land preparation, weeding and etc). Likewise, the ease of seed collection of Mezrut grass is simple while both Mechello and Rhodes grass with medium ease of seed collection.

Farmers also responded that both Mezrut and Mechello grass genotypes were used for gully treatments and degraded area rehabilitation as biological conservation in combination with physical structures. Generally, farmers preferred and appreciated both Mezrut and Mechello grass genotypes as main sources of livestock feed via improved forage production strategies in different land use types and means of soil conservation. Farmers finally elaborated the importance of both Mezrut and Mechello as livestock feed by no more livestock production without these grass genotypes.

Discussion

Days to emergence, 50% flowering and maturity

The result of the study revealed variability in days to emergence, 50% flowering and maturity among the three grass genotypes. Both local grass genotypes emerge earlier; easily reach to 50% flowering and maturity, indicating their tolerance to moisture stress areas. Early maturity is a relatively important agronomic characteristic and is measured by such criteria as days to flowering or days to maturity (Singh and Rachie 1985). The days to 50% flowering of Mezrut grass was corroborated but the days to 50% flowering of both Mechello and Rhodes grass were higher than the values reported by Jorge et al (2008) who found that the average results ranging from 40 to 57 days to reach to 50% flowering for 68 different buffel grass accessions in Zwai experimental site of the Ethiopian Rift valley. This might be due to environmental and genetic differences.

Dry matter herbage and seed yield

Mezrut and Mechello grasses showed significance comparative advantage over the standard check across the tested locations in both dry matter herbage and seed yield. The dry matter yield (DMY) of Mezrut (22.33 tone/ha) and Mechello (17.67 tone/ha) is from a single harvest and is much higher than the DMY of Rhodes grass (8.74 tone/ha in 2012 and 9.1 tone/ha in 2013) in mid-altitude areas of Amhara region, Ethiopia which was reported by Yenesew et al (2015). These indigenous grasses have higher DMY than buffel grass (2-9 tone/ha) and different Napier grass accessions under different conditions of Ethiopia (ranges from 7.05 ton/ha to 13.06 ton/ha) as reported by ICARDA (2014) and Gezahagn et al (2016), respectively. The dry matter yield of both Mezrut and Mechello were also considerably higher than the annual dry matter yield of Cenchrus Ciliaris Cultivar Biloela (13.9 ton/ha), Panicum Coloratum Cultivar Bambatsi (13.5 ton/ha), Panicum Maximum Cultivar Gatton (9.5 ton/ha), Chloris gayana cultivar Samford (9.0 ton/ha) and Chloris gayana cultivar Pioneer (7.0 ton/ha) in NLRI MPwapwa (Kusewa et al 1987). The dry matter of panicum (21.3 ton/ha in Alupe site and 22.3 ton/ha in kakamega site) reported in Kenya by Munyasi et al (2015) was higher the average dry matter yield of both Mechello and Rhodes grass but similar with the average dry matter of Mezrut obtained in the current study. The average dry matter yield of the three grass genotypes attained in the current study was lower than the dry matter yield of Napier Cultivar Ouma (ranges from 30.9 ton/ha in Alupe site and 32.3 ton/ha in kakamega sites of Kenya) (Munyasi et al 2015) but higher than the dry matter yield per a single cut of four Napier grass cultivars evaluated at Universiti Puta Malaysia (Zailan et al 2018). The dry matter yield differences among different grass species and grass varieties or cultivars might be due to genetic and environmental differences. The forage biomass yield differences of the same grass varieties or cultivars in different production environments of different countries is likely arises due to genotype by environment interaction.

Nutritional value

The minimum CP content in ruminant diet should be around 6.0-8.0% of the dry matter for adequate activity of rumen microorganism (Van Soest 1994), suggesting that the hay of Mezrut at both onset and 50% flowering and Mechello at onset flowering are more than twice needed rations. Mezrut grass is superior in CP to standard check, Rhodes grass whereas Mechello (8.76% CP) revealed similar CP with the standard check at 50% flowering. CP content of Mezrut and Mechello is higher at onset of flowering. Mezrut at onset (14.53% CP) and 50% flowering (13.88% CP) and Mechello (13.56% CP) at onset flowering have better CP content than buffel grass (9.6%CP) and Desho grass (11% CP) at 50% flowering reported by ICARDA (2014) and Bezabih et al (2016), respectively. The CP content of Mezrut at onset (14.53%) and 50% Flowering (13.88%) and Mechello at onset (13.56%) and 50% flowering (8.76%) was higher than in reports for Desho grass in different areas (Waziri et al 2013, Heuze and Hassoun 2015 and Asmare et al 2017). However, the cp content of Mezrut at both onset and 50% flowering and Mechello at onset flowering was nearly similar to the mean CP content of Napier (ranges from 13.2% to 13.9%) grass under intensive management of Nitrogen fertilizer and irrigation in Thailand (Sumran et al 2009). Furthermore, the mean CP content of all grass genotypes at 50% flowering in the current study was within the range of (5.9 -13.8%) reported for Pennisetum Species (Napier grass) by Kanyama et al (1995) and Kahindi et al (2007).

The OM% of Desho grass (89.78%) reported in Andassa Livestock Research Center by Asmare *etal*. (2017) was similar with the OM% of Mechello grass (89.9%) but higher than the OM% of Mezrut grass at 50% flowering in the current study. Moreover, the average OM% of both Mezrut and Mechello at 50% flowering was lower than OM% of Desho grass evaluated in Lemo and Angacha of South of Addis Ababa (Bezabih *etal*., 2016). Dried organic matter digestibility (IVDOMD) of Mezrut (57.16%) has similar IVDOMD with Rhodes grass (65%) but Mechello (50.74%) has lower IVDOMD than the standard check at 50% flowering. The Invitro dry organic matter digestibility of all Mezrut (57.16%), Mechello (50.74%) and Rhodes grass (65%) at 50% flowering was higher than the IVDOMD of Desho grass in Andassa Livestock Research Center of Ethiopia (Asmare et al 2017) but lower than the invitro dry organic matter digestibility of Napier grass (ranges 74.7%-75.5%) under intensive management of Nitrogen fertilizer and irrigation of Thailand (Sumran et al 2009).

The neutral detergent fiber (NDF%) of reported for Desho grass in Lemo and Angacha districts of South of Addis Ababa (Bezabih et al 2016) was similar with the NDF% of Mezrut but lower than the NDF% of Mechello at 50% flowering in the current study. Furthermore, the mean NDF% content of both Mezrut and Mechello at 50% flowering in the current study was with the range values (66.10- 71.80%) and (66.9-68.2%) reported for Napier grass in Malaysia by Halim et al (2013) and in Thailand by Sumran et al (2009), respectively. However, the NDF% of both Mezrut and Mechello at 50% flowering was lower than the values reported for Desho grass in Andassa Livestock Research Center (Asmare et al 2017).

The mean ADF% content of Mezrut grass in the current study was the ADF% content of Desho grass in Andassa Livestock Research center (Asmare et al 2017) and Napier grass under intensive management of Nitrogen fertilizer and Irrigation of Thailand (Sumeraw et al 2009). However, the ADF% content of Mechello at 50% flowering was higher than the ADF% content of Desho grass reported in Andassa Livestock research center (Asmare et al 2017) and Napier grass under intensive management of Nitrogen fertilizer and Irrigation of Thailand (Sumeraw et al 2009). Moreover, the ADF% content of both local grasses in the current study was higher than the ADF % content of Desho grass in Lemo and Angacha districts of South of Addis Ababa and Nine Napier grass varieties in Malaysia reported by Bezabih et al (2016) and Halim et al (2013), respectively.

Registration and description of the candidate grass genotypes

The National Variety Releasing Committee (NVRC) visited the local grasses in all locations at stage of 50% flowering. After a thoroughly evaluations (i.e. after cross checking the analyzed data with their field observations and the interviewed farmers' responses on the merits of both grasses), the NVRC decided to release and be registered both local grasses.

Table 6: Variety Descriptors (Passport Data) for Newly Released Mezrut Grass Genotype

	Morphological and other characteristics of the Variety	**Description of grass genotype**
1	New Variety	
1.1	Variety	**Mezrut (መዝሩጥ)**
1.1.1	Agronomic and morphological characteristics	
	Adaptation area	For relatively low to high moisture areas of lowland Tigray and similar agro ecologies of Ethiopia. **Altitude** (550-1500 m.a.s.l.); **Rainfall (**500-850**mm); Mean annual temperature** (17.5 - 41.7 ^{o}**c**)
	Seeding rate/ Broadcasting (Kg/ha)	10-12
	Planting date	End June to early July
	Fertilizer rate (Kg/ha)	No fertilizer is applied
	Days to forage harvesting (50 % Flowering)	51
	Days to maturity	87
	Plant height at forage harvest (cm)	130-135 m
	Flower color	White
	Seed color	White
	Seed size	Small
	Forage biomass Yield (DMY ton/ha)	20.3
	Seed (Qt/ha)	30.8
	Maturity group	Early
	Number of tillers	12-5
	Growth type	Erect
	Forage Quality (50% Flowering)	CP (13.88%), Ash (16.29%), OM (83.71%), DM (91.59%), IVOMD (67.16%), NDF (64.55%), ADF (42.29%), Lignin (7.28%)
	Leaf to Stem Ratio	60 to 40
	Mode of offer and Utilization	Cut and carry system, Direct grazing, Hay, as silage
	Proper stage of harvesting for quality hay	50% flowering
	Year of release	2017
	Breeder (Maintainer)	**Humera Agricultural Research Center, TARI**

Table 7. Variety Descriptors (Passport Data) for Newly Released Mechello Grass Genotype

	Morphological and other characteristics of the Variety	**Description of grass genotype**
1	New Variety	
1.1	Variety	**Mechello (ምጨሎ)**
1.1.1	**Agronomic and morphological characteristics**	
	Adaptation area	For low moisture areas of lowland of Tigray as well as similar agro ecologies of Ethiopia. **Altitude** (500-1000 m.a.s.l.); **Rainfall (**380-803**mm); Mean annual Temperature (**21.6 - 42.4 ^{o}**c)**
	Seeding rate/ Broadcasting (Kg/ha)	10-13
	Planting date	End June to early July
	Fertilizer rate (Kg/ha)	No fertilizer is applied
	Days to forage harvesting (50 % Flowering)	65
	Days to maturity	80
	Plant height at forage harvest (cm)	150-160 cm
	Flower color	Red
	Seed color	Red
	Seed size	Small
	Forage biomass Yield (DMY ton/ha)	18.9
	Seed (Qt/ha)	29
	Maturity group	Early
	Number of tillers	8-30
	Growth type	Erect
	Forage Quality (50% Flowering)	CP (13.6%), Ash (12.1%), OM (87.9%), DM (92.3%), IVOMD (63.8%), NDF (65%), ADF (44.7%), Lignin (5.6%)
	Leaf to Stem Ratio	55 to 45
	Mode of offer and Utilization	Cut and carry system, direct grazing, hay, as silage
	Proper stage of harvesting for quality hay	Onset of flowering
	Year of release	2017
	Breeder (Maintainer)	**Humera Agricultural Research Center, TARI**

Conclusion and Recommendations

Mezrut and Mechello grasses become recognized as livestock feed by the National Variety Releasing Committee. Both local grass varieties gave higher dry matter yield under rain fed condition than the standard check .So; it is understandable that these varieties are important forage grass species for alleviating the feed scarcity in terms of quantity feed so as to ensure improved and sustainable livestock production. Likewise, Mezrut grass (13.88% CP) has superior CP than the standard check (9.3% CP) but Mechello has similar CP with the standard check at 50% flowering. Both Mezrut (14.53%CP) and Mechello (13.56%CP) have higher crude protein content at onset of flowering. The appropriate harvesting time for quality hay of Mechello grass is onset of flowering and Mezrut grass is 50%flowering. Mezrut and Rhodes grass have similar dried organic matter digestibility whereas Mechello has low dried organic matter digestibility. Besides, the varieties scored higher seed and forage biomass yield per hectare, mature and reach to 50% flowering earlier than the standard check and have better disease, pests and drought resistance. They are suitable for improved forage production strategies in both irrigable and rain fed conditions of different environmental niches of western zone of Tigray like rehabilitation of degraded grazing lands, roadsides, marginal forage development and backyard forage establishment through direct over sowing. They are also used for contour forage strips strategies and permanent pasture forage strategy –for cut and carry feeding system feeding. Feeding trial should be conducted in the future. It is also highly recommended that demonstration and popularization of the local grass forages in low land moisture stressed areas of western zone of Tigray and other similar areas should be undertaken for better and sustainable utilization and adoption of the grasses as livestock feed.

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