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Editors

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Amhara Regional Agricultural Research Institute (ARARI)

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Effect of deficit irrigation on yield of onion using furrow irrigation methods in Kobo Girrana Valley, Ethiopia

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Abstract

Deficit irrigation (DI) is very essential in water scarce areas. Efficiency of irrigation can be improved by making the right decision regarding to irrigation scheduling and irrigation application techniques. This experiment was conducted to determine the most sensitive growth stages of onion to water stress so as to maximize water use efficiency and yield of onion. The study was carried out for two consecutive years (2011 and 2012). Four growth stages (Initial (I), Development (D), Mid (M) and Late (L) stages) and four water application depths (100% application depth, 25% deficit, 50% stress and 75% deficit) were studied in factorial experiment. Irrigation was applied through calibrated siphons with an irrigation interval of six days under furrow irrigation methods. All relevant data were collected and analyzed and significant treatment means were separated using least significant difference at 5%. The result showed that effect of treatments on bulb diameter and bulb weight, marketable yield and total yield was significant. The highest marketable yield (20.96 t ha^{-1}) was obtained from 25% stress at initial stage followed by (20.77 t ha^{-1}) 50% stress at initial stage while the lowest marketable yield (13.94 t ha^{-1}) was obtained from 75% stress at all stages. Full application of 40mm irrigation depth especially at the late stage had resulted in the highest unmarketable yield while stressing by 50% at the initial stage gave the highest marketable yield with a seasonal irrigation requirement of 540mm in the growing season. Therefore, it is recommendable to apply irrigation water at 50% stress (20 mm irrigation depth) at initial, development and mid stages and 40 mm at late stages every six days for onion.

Key words*:* deficit irrigation, growth stage, stress, water use efficiency, yield

Introduction

Agriculture in eastern Amhara of Kobo Girana valley is rainfall dependent. However, the rainfall is erratic and unreliable in its distribution and amount. As a result, recurrent drought and crop failure are common phenomena. Irrigation agriculture is essential to sustain food production in this part of the region. When practicing irrigation, it is quite important to utilize the scarce water resource efficiently, which can be achieved by deficit irrigation practice. Regulated deficit irrigation is the practice of irrigating below crop water requirement. Deficit (regulated deficit) irrigation is one way of maximizing water use efficiency (WUE) for higher yields per unit of irrigation water applied. It can be carried out by either withholding or skipping irrigation event or reducing the amount of water applied per irrigation at some growth stages of the crop known to be less critical to moisture stress. This practice, although leads to reduction in crop yields in many instances, it saves water, labor and in some cases energy.

Research evidences has shown that higher crop water productivities are sometimes recorded with deficit irrigation practice, especially if the moisture stress resulting from the deficit is not so severe. Different works showed that under conditions of scarce water supply, deficit irrigation can provide greater economic returns that maximizing yields per unit of area (Teferi G., 2015, Nagaz. et al., 2012, Geerts and Raes, 2009, English and Raja, 1996; Kirda et al., 1999). There is no doubt that there is a growing interest in deficit irrigation as a means of improving water productivity. However, there are reports elsewhere showing onion is very responsive to water. According to Anisuzzaman et al. (2009), onion requires frequent irrigations because most of the crop water requirement is extracted from the top 300 mm depth of soil, and very little water from depths below 600 mm; thus the upper soil areas must be kept moist to stimulate root growth and provide adequate water for the plant. Shock et al. (2000) reported that onion yield and grade were very responsive to careful irrigation scheduling and maintenance of optimum soil moisture and that any soil moisture stressed even below field capacity caused yield reduction. Bekele and Tilahun (2007) in Ethiopia, found that water deficit at first and fourth growth stages, gave no significant different yield from the optimum irrigation application. Furthermore, when water stress was imposed 30 days after transplanting for a period of 15 days, leaf area and bulb growth were considerably decreased with a reduction of 17-26% in one yield (Batta et al., 2006).

In practicing DI, the irrigator aims to increase water use efficiency by reducing the amount of water at irrigation or by reducing the number of irrigations. Therefore, the irrigator must decide what deficit level to allow, what level has been reached, when not to allow a deficit to occur and when to apply water at a lower level of adequacy to achieve the highest water use efficiency at minimum cost. Deficit irrigation is quiet essential in water scarce areas like in eastern Amhara but no study have been carried out earlier in this regard. A recent study conducted in Kenya showed that DI at vegetative and late growth stages influence yields in a positive linear trend with increasing quantity of irrigation water and decreasing water stress reaching optimum yield of 32.0 t ha^{-1} at 20% water stress (T80) thereby saving 10.7% irrigation water on onion bulb yield (Tsegaye et al., 2016).

Furthermore, the actual evaluation of stress related to the yield due to soil water deficit during the onion-growing season can be obtained by the estimation of the yield response factor (Ky) that represents the relationship between a relative yield decrease (1-Ya/Ym) and a relative evaporation deficit (1–ETa/ETm). Doorenbos and Kassam (1986) estimated the average values of Ky is 1.5 during the onion-growing season. Vaux and Pruitt (1983) suggest that it is highly important to know not only the Ky values from literature but also those determined for a particular crop species under specific climatic and soil conditions. This is because Ky may be affected by other factors besides soil water deficiency, namely soil properties, climate (environmental requirements in terms of evapotranspiration), growing season length and inappropriate growing technology. Water deficit effect on crops yield can be presented in two ways, for individual growth periods or for the total growing season. Kobossi and Kaveh (2010) suggested Ky values for the total growing period instead for individual growth stages as the decrease in yield due to water stress during specific periods, such as vegetative and ripening periods, is relatively small compared with the yield formation period, which is relatively large.

Conclusively, DI during vegetative development and late season stages, which are considered to be water stress tolerant stages of onion, some water would be saved (David et. al, 2016). The specific objectives of this study were: (i) to determine onion yield in response to various water deficit application levels and during stress tolerance stages and (ii) to determine irrigation water use efficiency of the onion

Materials and methods

Location of experimental site

The field experiment was conducted in the irrigation season of 2011 and 2012 for two consecutive years at kobo irrigation scheme. The site is located at about 50 kilometers from Woldiya town to the North-east direction and situated at 12.08^0 N latitude and 39.28^0 E longitudes with an altitude of 1470 m.a.s.l. The rainfall is about 630 mm with average daily reference evapo-transpiration rate of 5.94 mm. The soil type in the experimental site is silty clay loam with average field capacity (FC) and permanent wilting point (PWP) of 38% and 21.0% on volume basis respectively. And the soil has average infiltration rate of 8 mm hr^{-1} and 7.8 pH value. It contains total N of 0.1% and available P of 10.86 mg of P_2O_5 kg^{-1} of soil.

Experimental set up

The study consisted of 16 treatments composed of four growth stages and four water application depths. The growth stages were Initial (I), Development (D), Mid (M) and Late (L) stages and the water levels were 100% application depth (40mm), 25% stress (10mm), 50% stress (20mm) and 75% stress (30mm). Treatments were arranged in RCBD designs with four replications. The reference crop evapotranspiration was determined based on the Penman-Monteith method and the crop water requirement was determined by a CROPWAT 8.1 computer program software based on the reference crop evapotranspiration and crop coefficient factors at various growth stages.

Seedlings were transplanted from nursery station after 30 days of emergence. Transplantation was carried out with proper agronomic spacing of 40 cm bed including furrow, 20cm between rows on the bed and 10 cm between plants. After transplanting for the first five days irrigation were applied every day to establish the seedlings and followed by six day scheduling. The variety Bombay red of onion was used as a test variety. The recommended rate of phosphorus and nitrogen was used. Di-ammonium phosphate (DAP) was the source of phosphorus and used at transplanting while urea was used as sources of nitrogen and applied half at transplanting and the remaining half after 45 days of transplanting. The rate of DAP was 100 kg ha^{-1}. .

Irrigation water application method

Full optimal crop water requirement (100%) was determined based on CROPWAT 8.1 software program. The irrigation interval was six days for all treatments and the amount of water at each irrigation time was measured by siphons in furrow irrigations (Table 1 and Table 2).

Table 1. Number of irrigation cycles

Growth stages	Initial	Development	Mid	Late
Day length	18	30	30	12
Irrigation cycle	3	5	5	2

Totally there were 15 irrigation cycles in the growing season of onion crop (Bombe red variety) with a total growing length is about 95 days. A seasonal net irrigation requirement was also estimated based on depths of irrigation and growing day lengths.

Table 2. Treatments

Treatments	Irrigation amount and growth stages	Irrigation depths (mm)	Water applied (mm)
1	Full irrigation (optimal watering)	40	600
2	25% deficit @ all stage	30	450
3	25% deficit @ I stage	30	570
4	25% deficit @ D stage	30	550
5	25% deficit @ M stage	30	550
6	25% deficit @ L stage	30	580
7	50% deficit @ all stage	20	300
8	50% deficit @ I stage	20	540
9	50% deficit @ D stage	20	500
10	50% deficit @ M stage	20	500
11	50% deficit @ L stage	20	540
12	75% deficit @ all stage	10	150
13	75% deficit @ I stage	10	510
14	75% deficit @ D stage	10	450
15	75% deficit @ M stage	10	450
16	75% deficit @ L stage	10	540

Data Analysis

Data collected were subjected statistical analysis using SAS version 9 computer software. Mean comparison was done y using least significant difference test at 5% probability level. Correlation among the parameters was computed using Pearson's simple correlation coefficient.

Computation of water productivity

For each treatment, the water productivity (kg m^{-3}) was calculated using the following formula as described by Michael (1997). The water productivity simply referred to the output (crop yield, economic returns) with respect to the water input in crop production. In this study, crop water productivity is defined with respect to yield and seasonal water supply, and the expression is given as:

$$\mathrm{CWP}\left(\frac{\mathrm{Kg}}{\mathrm{M}^3}\right) = \left(\frac{\text{Bulb yield (kg ha}^{-1})}{\text{Waterapplied (M}^3}\right)$$

Results and discussion

Yield and yield components

The finding of the research showed that the interaction effect of treatments on bulb diameter, bulb weight, marketable yield and total yield was insignificant (Table 3). Deficit irrigation to 75% at all growth stages or received only 25% of the ideal full irrigation water throughout the growing season produced the lowest marketable yield (13.94 t ha^{-1}). On the other hand, the highest marketable yield (20.96 t ha^{-1}) was obtained from only 25% deficit at initial stage. Singh and Sharma (1991) reported that more frequent irrigation produced higher yield of onion (17 to 27.t ha^{-1}) in the sandy loam soil of many areas. It was expected that irrigation with 75% deficit at all stage will produce the lowest bulb yield while fully irrigated treatment (100% of CROPWAT 8.1 generated depth) will produce the highest bulb yield. While full irrigation water application in all growth stages was highly affected the marketable yield of onion.

Table 3. Analysis of variance (ANOVA) result

Source of variation	DF	Mean square Bulb diameter	Bulb weight	Marketable yield	Total yield	Water productivity
Replication	3	0.20	240.1	21.349	35.03	1.86
Treatment	15	0.17	281.0	23.04	36.46	17.94
F Treatment		1.29	2.1	3.72	5.82	5.56
treatment*year	15	0.09	205.9	7.46	4.39	0.52
Error	45	0.13	133.9	6.20	6.27	3.23
F interaction		0.71	1.54	1.22	0.70	0.16

The experimental treatments showed significant effects on bulb diameter and bulb weight and a high significant difference in marketable yield and total yield (Table 4).

Table 4. Treatments effect on marketable yield and yield components

Treatment	Bulb diameter (cm)	Bulb weight (gm)	Marketable yield (t ha^{-1})	Total yield (t ha^{-1})
(Full irrigation optimal watering)	5.45	100.5	18.47	21.08
25% deficit @ all stage	5.49	102.8	18.55	18.80
25% deficit @ I stage	5.75	110.5	20.96	21.77
25% deficit @ D stage	5.73	108.0	18.31	19.24
25% deficit @ M stage	5.64	108.1	19.32	20.09
25% deficit @ L stage	5.61	108.3	18.58	19.01
50% deficit @ all stage	5.60	101.1	16.96	17.05
50% deficit @ I stage	5.71	108.3	20.77	22.02
50% deficit @ D stage	5.75	106.9	20.59	20.40
50% deficit @ M stage	5.77	116.0	18.83	19.87
50% deficit @ L stage	5.66	105.7	20.23	20.74
75% deficit @ all stage	5.32	92.5	13.94	14.08
75% deficit @ I stage	5.47	100.3	18.32	18.07
75% deficit @ D stage	5.48	97.5	17.69	16.80
75% deficit @ M stage	5.52	98.5	18.32	16.74
75% deficit @ L stage	5.82	108.8	19.20	20.31
CV (%)	5.4	11.1	13.3	11.00
LSD (0.05)	0.30	11.49	2.471	2.08

Treatment of deficit irrigation to 75% at all growth stages that received only one-fourth of the ideal full irrigation water throughout the growing season produced the lowest marketable yield of 13.94 t ha^{-1}. On the other hand, the highest marketable yield of 20.96 t ha^{-1} was obtained from the treatment with 25% deficit at initial stage. Singh and Sharma (1991) reported that more frequent irrigation produced higher yield of 17 to 27.4 t ha^{-1} in the sandy loam soil of many areas. It was expected that least irrigation treatment (75% deficit at all stage) will produce the lowest bulb yield while fully irrigated treatment (100% of CROPWAT 8.1 generated depth) will produce the highest bulb yield. While full irrigation water application in all growth stages was highly affects marketable yield of onion.

Many studies have been reported on irrigation of onions (Doorenbos and Kassam (1986). These studies gave clear proof that the bulb and dry matter production are highly dependent on appropriate water supply. Onion crop is known to be very responsive to irrigated water. For optimum yield, it is necessary to prevent the crop from experiencing water deficit, especially during the bulbing stage. During the early vegetative growth periods the crop appears to be less sensitive to water deficit; excessive irrigation during this period can lead to a delayed start of bulbing and a reduced bulb development (Doorenboset al, 1979). Deficit irrigation occurring during the last or late growing stage in each deficit level couldn’t affect the marketable yield and the yield reduction was experimentally non-significant. This yield reduction would have been much greater had the crop been subjected to water stress during any of the previous stages. It should be noted at this point that in the study area, many farmers withhold irrigation during this last stage, as well as providing inadequate water throughout the growing season. This situation causes major yield reductions. For optimum yield, it is necessary to prevent the crop from experiencing water deficit, especially during the bulbing stage. During the early vegetative growth periods the crop appears to be less sensitive to water deficit. Excessive irrigation during this period can lead to a delayed start of bulbing and a reduced bulb development (Nigus, 2013). There was no significant difference between treatments of stressed 25% at first (I) stage, stressed 50% at first (I) stage, development stage (D) and late (L) stage. Deficit to 75% and 50% at all growth stages affects marketable yield. Deficit to 25% and 50% at I stage didn’t affect the marketable yield. But deficit to 25% and to 50% at I stage saves 30mm and 60mm; respectively seasonal water requirement compared to the full application.

During the time interval between two consecutive irrigation applications, soil water storage for full application and actual evapotranspiration is assumed to be equal to maximum evapotranspiration (Nigus, 2013). Hence, the testing crop (onion) was not imposed to water stress and therefore Ya =Ym (actual yield equals maximum yield). Hence, it is possible to derive the relationship between relative yield reduction and relative evapotranspiration deficits. Water stress for all stages (75%), resulted in the highest yield penalty (Table 5). The negative value (Table 5) indicates the yield gained from above the optimum application and the positive one is the yield lose or penalty from the optimum application. Stressed to 75% at all growth stages gave the highest yield reduction 4.53 t ha^{-1} (22.4%). The highest additional yield gain from the optimum irrigation water application was obtained due to deficit effects of 25% and 50% at initial stage. Full application especially at initial and late stage leads to occurrence of unmarketable yield or yield reduction.

Table 5. Relative yield reduction in the experimental area

Treatments	Actual yield (t ha^{-1})	Yield reduction (t ha^{-1})	%yield reduced	Rank
(Full irrigation optimal watering)	18.47	0	0.0	10
25% deficit @ all stage	18.55	-0.08	-0.4	9
25% deficit @ I stage	20.96	-2.41	-13.0	2
25% deficit @ D stage	18.31	0.16	0.8	12
25% deficit @ M stage	19.32	-1.01	-5.5	5
25% deficit @ L stage	18.58	-0.11	-0.6	8
50% deficit @ all stage	16.96	1.51	8.1	15
50% deficit @ I stage	20.77	-2.3	-13.6	1
50% deficit @ D stage	20.59	-2.12	-10.2	3
50% deficit @ M stage	18.83	-0.36	-1.7	7
50% deficit @ L stage	20.23	-1.4	-7.4	4
75% deficit @ all stage	13.94	4.53	22.4	16
75% deficit @ I stage	18.32	0.15	1.1	13
75% deficit @ D stage	17.69	0.63	3.4	14
75% deficit @ M stage	18.32	0.15	0.8	12
75% deficit @ L stage	19.2	-0.73	-4.0	6

As it was observed in Table 6, there was a significant difference between treatments in water productivity. Water productivity value ranges from 3.392 kg m^{-3} due to 25% deficit at late stage to 9.613 kg m^{-3} due to 75% deficit at all stages. In areas where water is the most limiting resource to production, maximizing WP may be more profitable to the farmer than maximizing crop yield. This is because the water saved by applying deficit irrigation becomes available to irrigate more land since the latter is not the limiting factor. In northern Syria it was found by applying 50% of full supplemental irrigation requirements would reduce yield by 10 to 15% while applying the saved water to lands otherwise rain-Ribfed increased the total farm production by 38% (Oweis, unpublished work).

Table-6: Effects of deficit irrigation on water productivity

Treatment	Water productivity (kg m^{-3})		
	First year	Second year	combined
(Full irrigation optimal watering)	3.58	3.87	3.72
25% deficit@ all stage	3.70	4.96	4.33
25% deficit @ I stage	3.31	4.81	4.06
25% deficit @ D stage	2.67	4.64	3.65
25% deficit @ M stage	3.20	4.57	3.89
25% deficit @ L stage	2.55	4.24	3.39
50% deficit @ all stage	4.38	7.59	5.98
50% deficit @ I stage	3.58	5.11	4.34
50% deficit @ D stage	3.50	5.16	4.33
50% deficit @ M stage	3.23	4.92	4.08
50% deficit @ L stage	3.10	4.71	3.90
75% deficit @ all stage	6.53	12.70	9.61
75% deficit @ I stage	2.89	4.50	3.70
75% deficit @ D stage	2.80	4.95	3.87
75% deficit @ M stage	2.83	4.99	3.91
75% deficit @ L stage	3.35	4.66	4.01
CV (%)	9.8	16.2	16.3
LSD (0.05)	0.48	1.25	0.72

Conclusion and recommendation

One of the irrigation management practices which could result in water saving is deficit irrigation. By maintaining the moisture content of the soil below the optimum level during specific growth stages of the season or throughout the growing season, it is possible to identify the periods during which water deficit would have a limited effect on crop production. Our experimental research result revealed that when deficit irrigation water was forced in the early and late growing stages, high yield could be easily obtained while provided adequate watering in the remaining two growing stages. The most critical growing stages for maximum onion production and water productivity are development and mid growth stages. Meeting the full water requirement during the first two stages is not advisable if water shortage can't be avoided during the remaining of the season and full irrigation water application particularly at initial and late stages leads to occurrence of highest unmarketable yield. Good watering early in the season allows the crop to develop an important cover and a limited root system. Deficit water application to 75% for all growing stages resulted in high yield penalty per unit of irrigation water deficit. Deficit to 50% at initial growth stage gave the highest marketable yield with a seasonal irrigation requirement of 540 mm in the growing season that saves about 60 mm water (10% additional water saving). It is also advisable irrigating onion at 6 days interval with 20 mm irrigation depth at initial, development and late stages while 40 mm at mid stage to achieve high yield for the study area.

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Effect of irrigation regime on yield and water use of tomato in western Amhara, Ethiopia

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Abstract

This study investigated the effects of different irrigation regimes on yield and yield components of Tomato at Koga and Rib irrigation schemes, western Amhara during 2012-2013. The treatments were factorial combinations five irrigation depths (50%, 75%, 100%, 125% and 150%) and two irrigation intervals (7 and 10 days interval) and laid out in a randomized complete block design with three replications. Data on yield and yield components were collected and analyzed using SAS 9 software and significant treatment means were separated using least significant difference at 5%. Application of optimum irrigation regime increased the total and marketable yield over the deficit and excess irrigation regime plot, and their interaction showed a significant effect on the average marketable, total yield and water productivity of Tomato. The highest marketable yield at Koga (61.2 t ha^{-1}) was obtained from 125%CWR at seven days interval while the highest marketable yield at Rib (45.5 t ha^{-1}) was obtained from 150%CWR at ten days interval. Therefore, for Koga and similar agro ecologies tomato can be irrigated with 125%CWR at seven days interval and at Rib and similar agro ecologies tomato can be irrigated with 150%CWR at ten days interval.

Key words: Irrigation depth, irrigation regime, schedule, tomato

Introduction

Recently precision agriculture in humid areas is already being used to increase yield and water productivity thereby making irrigation feasible (DeJonge and Kaleita, 2006). Appling optimum amount at right time as well as at critical growth stages have crucial impact (Upton, 1996; Michael, 1998). Thus, to attain stable crop yields with unpredictable storm frequency variability, irrigation scheduling is often necessary.

The national average tomato (*Lycopersicon esculentum* L.) fruit yield in Ethiopia is often low (12.5 t ha^{-1}) compared to the neighboring African countries like Kenya (16.4 t ha^{-1}) (FAO, 2004). Current productivity under farmers' condition is 9.0 t ha^{-1}, while yields up to 40.0 t ha^{-1} were recorded on research plots (Tesfaye, 2008). Several factors are responsible for this discrepancy, among which irrigation water management are the foremost factors (Fekadu and Dandena, 2006). Many investigations have been carried out worldwide regarding the effects of irrigation regime on yield of vegetables (Samson and Ketema, 2007; Pejic et al., 2011). However, most of these studies assessed the effect of reduced water stress (irrespective of appropriate irrigation scheduling to the entire growth stage on fruit yield).

Tomato plants have high water requirement throughout the growing period until fruiting occurs. The plants are resistance to moderate drought. The tomato fruit contains 90-96% water. Insufficient water during flowering and fruit development leads to flower and fruit drops, blossom end rot, physiological disorder and subsequently low fruit yield and quality. On the other hand excessive irrigation creates anaerobic soil condition and consequently causes root death, delayed flowering, and fruit disorders. Therefore, proper irrigation water management at different development stages is the most important practice to be considered for high quality fruit production.

Among the common irrigated vegetables, tomato shares the largest in both area coverage and local consumption under irrigation in Ethiopia Particularly, North West Amhara region. However, the largest production of tomato is not supported with improved water management practices to improve its productivity and fruit quality. Hence, the objectives of this study were to determine the crop water requirement and irrigation schedule of tomato and to statistically determine effect of irrigation regime on yield and water productivity in western Amhara.

Materials and methods

Site description

The experiment was conducted during 2012 and 2013 at Koga and Rib irrigation schemes, west Amhara, Ethiopia. Koga irrigation scheme is located in Mecha District; 41 kilometres from Bahir Dar on the way to Addis Ababa via Debremarkos (37°7'29.721"Easting and 11°20'57.859"Northing and at an altitude of 1953 m a.s.l). The average annual rainfall of the area was about 1118 mm. The mean maximum and minimum temperatures are 26.8 ^{0}C and 9.7 ^{0}C respectively. The soil type is Nitisols and has low available phosphorous (6.12 ppm), medium total nitrogen (0.21%), and strongly acidic soil reaction (soil pH 4.6). The field capacity (FC) and permanent wilting point of the study area were 32 (%w/w) and 18 (%w/w) respectively.

Rib irrigation site is located in Fogera District, 60 kilometres far from Bahir Dar on the way to Gondar (37°25' to 37°58' Easting and 11°44' to 12°03' Northing and at an altitude of 1774 m.a.s.l). It receives 1400 mm mean annual rainfall. The mean daily maximum and minimum temperature of the study area was 30°c and 11.5°c. The area is characterized as mild altitude agro-ecology. The soil type of the experimental site is Fluvisols which have high available phosphorous (36.71 ppm), very low total nitrogen content (0.003), high cation exchange capacity (CEC) (33.0) and neutral soil reaction (pH = 6.7). The field capacity (FC) and permanent wilting point (PWP) of the study area were 59.25 (%w/w) and 21 (%w/w); respectively.

Methods

CROPWAT 8.0 for Windows was used to estimate daily reference crop evapotranspiration and generate the crop water requirement and the irrigation schedule for Tomato in the study areas (Table 1 and 2). Calculations of the crop water requirements and irrigation schedule were carried out taking inputs of climate, soil and crop data. In order to estimate the climatic data (wind speed, sunshine hours, relative humidity, minimum and maximum temperature) LOCCLIM, local climate estimator software (FAO, 1992) were used for both Koga and Rib where there is no class A meteorological stations. The estimator uses real mean values from the nearest neighbouring stations and it interpolated and generated climatic data values for the study site. Based on the technology we use, we assume 70% application efficiency both at Rib and Koga, and then the gross water requirement was calculated. The demand for water during the plants growing season varies from one growth stage to another. Values of potential evapotranspiration (ET_0) estimated were adjusted for actual crop ET. Table 3 and 4 shows CROPWAT 8 Windows tables for ET.

Principally, CROPWAT outputs generated by default were used to identify irrigation timing of when 100% of readily available moisture occurs and application depth where 100% of readily available moisture status is attained. To verify the CROPWAT output, field experiments were carried out for two consecutive years in both locations.

Table 1. Climate and ETo data of Koga

Month	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours	Rad MJ/m²/day	ETo mm/day
January	7.5	26.5	51	1	9.8	21.3	3.13
February	9.2	28	45	1	9.8	22.8	3.48
March	12	29.5	42	1	9.1	23.1	3.8
April	13.3	29.8	43	1	8.8	23.1	3.98
May	14.4	28.9	53	1	8.6	22.4	4.03
June	14	26.6	67	1	6.7	19.2	3.59
July	13.7	24	76	1	4.4	15.9	3.01
August	13.6	24	77	1	4.3	15.9	3
September	12.9	25.1	72	1	5.9	18.2	3.3
October	12.5	26.2	63	1	9	21.9	3.7
November	10.4	26.3	57	1	9.5	21.2	3.35
December	7.9	26.2	54	1	10	21	3.11
Average	11.8	26.8	58	1	8	20.5	3.46

Table 2. Climate and ETo data of Rib

Month	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours	Rad MJ/m²/day	ETo mm/day
January	4.6	30.5	54	2	9.2	20.3	3.12
February	6.3	33	51	2	10	22.9	3.73
March	8	33	49	2	10	24.4	4.17
April	9	32.7	51	2	8.5	22.6	4.07
May	10	31.6	65	2	6.7	19.6	3.76
June	10.4	28.5	80	2	5.4	17.4	3.41
July	9.8	25	85	1	1.6	11.8	2.39
August	10.1	25.5	86	1	6.7	19.6	3.57
September	9.8	27	82	1	9	22.9	4.08
October	7.4	29	76	2	10	23.2	3.99
November	6.7	30	69	2	10	21.6	3.55
December	5.6	30	61	1	7.4	17.3	2.81
Average	8.1	29.6	67	2	7.9	20.3	3.56

Table 3. Crop water and irrigation requirements of tomato at Koga

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Dec	3	Initial	0.6	2.02	22.2	0	22.2
Jan	1	Initial	0.6	2.06	20.6	0	20.6
Jan	2	Development	0.6	2.11	21.1	0	21.1
Jan	3	Development	0.71	2.63	29	0.1	28.9
Feb	1	Development	0.87	3.43	34.3	1	33.3
Feb	2	Development	1.02	4.27	42.7	1.4	41.2
Feb	3	Development	1.16	5	40	1.7	38.3
Mar	1	Mid	1.21	5.39	53.9	1.9	51.9
Mar	2	Mid	1.21	5.55	55.5	2.2	53.3
Mar	3	Mid	1.21	5.67	62.4	2.8	59.7
Apr	1	Mid	1.21	5.8	58	1.3	56.7
Apr	2	Late	1.19	5.81	58.1	0.8	57.3
Apr	3	Late	1.08	5.21	52.1	9.7	42.4
May	1	Late	0.96	4.66	46.6	19.3	27.3
May	2	Late	0.88	4.25	17	10.8	3.5
					613.3	53	557.7

Table 4. Crop water and irrigation requirements of tomato at Rib

Month	Decade	Stage	Kc Coeff.	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr. Req. mm/dec
Dec	3	Initial	0.6	1.87	20.6	0	20.6
Jan	1	Initial	0.6	1.87	18.7	0	18.7
Jan	2	Development	0.6	1.88	18.8	0	18.8
Jan	3	Development	0.69	2.25	24.7	0	24.7
Feb	1	Development	0.83	2.79	27.9	0	27.9
Feb	2	Development	0.96	3.35	33.5	0	33.5
Feb	3	Development	1.08	3.87	31	0	31
Mar	1	Mid	1.13	4.16	41.6	0	41.6
Mar	2	Mid	1.13	4.28	42.8	0	42.8
Mar	3	Mid	1.13	4.34	47.8	0.1	47.7
Apr	1	Mid	1.13	4.41	44.1	1.8	42.4
Apr	2	Late	1.1	4.38	43.8	2.6	41.1
Apr	3	Late	0.99	3.95	39.5	3.9	35.6
May	1	Late	0.87	3.49	34.9	1.7	33.2
May	2	Late	0.78	3.17	12.7	0.5	12.1
					482.3	10.5	471.7

Treatment setup

The on-farm trial was conducted in the dry season with ten different treatments in both location at Rib and Koga. Two irrigation intervals i.e. 7 and 10 days and five irrigation depths (50, 75,100,125 and 150% CWR) of variable depths at four growth stages are selected based on CROPWAT 8.0. Thus the following treatments were set and evaluated for verification of the CROPWAT prediction with field experimentation:

1. 50%CWR at 7 day interval
2. 75%CWR at 7 day interval
3. 100%CWR at 7 day interval
4. 125%CWR at 7 day interval
5. 150%CWR at 7 day interval
6. 50%CWR at 10 day interval
7. 75%CWR at 10 day interval
8. 100%CWR at 10 day interval
9. 125%CWR at 10 day interval
10. 150%CWR at 10 day interval

The experiment was arranged with factorial RCBD with three replications and carried out from December to April. The test crop tomato, a variety of Cochero, was planted 1m x0.3m, spacing between row and plants on 4 m by 6 m plot size at Koga and 4*3 at Rib. Spacing between plot and block was 1m* 1.5m. DAP fertilizer was applied at a rate of 200 kg ha^{-1} at planting and 100 kg Urea ha^{-1} was applied half at planting and the remaining half at 45 days after planting. All the agronomic practices were equally done for each treatment. Agronomic data such as stand count, total bulb yield, marketable yield, and unmarketable yield were collected up to 5 round. In addition water productivity was calculated as the ratio of marketable yield to amount of water consumed (Arega, 2003).

Data Analysis

The means of the above parameters were subjected to analysis of variance (ANOVA) using SAS version 9 computer software. Mean comparison was done by using least significant difference test at 5% probability level.

Results and discussions

Most parameters showed significant difference for the interaction of irrigation scheduling and crop water requirement. Effect of variable irrigation regime on yield and water productivity component is presented in the following tables (Table 5 and Table 6).

Marketable yield and fruit weight

The interaction effect of irrigation frequency and depth showed a highly significant difference in marketable yield of tomato ($P < 0.001$, Table 5). At Koga, the highest (61.2 t ha^{-1}) tomato marketable yield was obtained from 125%CWR at 7 day irrigation interval while the lowest (27.5 t ha^{-1}) was obtained from 125%CWR at 10 day irrigation interval, (Table 5). The result is in line with the finding of Solomon et al (2014), who reported the application of 14mm depth, of irrigation (i.e. 75% of Cropwat generated depth) at 11 days interval gave the highest marketable yield 55.73 t ha^{-1} around Jari, eastern Amhara. The reduction in marketable yield of tomato with an increased amount of water stress level of this test was consistent with previous work conducted on tomato as reported by Schoolberg et al. (2000). The results indicated that, the marketable fruit yield of tomato is influenced by irrigation frequency while not irrigation regime. Marketable yield of tomato increased with an increment of irrigation depth from 50-125%CWR at 7 day irrigation interval while not at 10 day interval. However, further increase in irrigation level did not bring significant effect on marketable yield of tomato, reductions in marketable yield of tomato at irrigation depth beyond 125%CWR at 7 days irrigation interval and beyond 7 days irrigation interval may be due to the fact that much higher irrigation depth and interval can adversely affect marketable yield through the development of physiological disorder such as aeration and also creating favorable environment for diseases.

The marketable bulb yield of tomato at Rib had a positive response for irrigation frequency and depth as well as for interaction ($p<0.05$) (Table 6). The highest (45.51 t ha^{-1}) and lowest (32.01 t ha^{-1}) tomato marketable yields were obtained from 150%CWR at 10 day and 50%CWR at 7 day irrigation interval, respectively (Table 6). Marketable yield of tomato increased with an increment of irrigation depth from 50-150%CWR at 10 day irrigation interval while not at 7 day interval. Similarly the highest non marketable yield (5.44 t ha^{-1}) was observed from the application of 100%CWR at 7 days interval. The source of un marketability was insect damage, disease and crack; but insect damage took the lion’s share. The tomato yield obtained from this is by far higher than the yield obtained from the convectional production as well as from the yield reported by Hanibal et al. (2014) at Megech, Ethiopia.

Table 5. Effect of irrigation depth and frequency on marketable, unmarketable and total yields and water productivity at Koga

Frequency	Depth	Marketable yield (t ha^{-1})	Un marketable yield (t ha^{-1})	Total yield (t ha^{-1})	Water Productivity (kg m^{-3})
7	50	41	5.9	46.9	7.55
7	75	39	5.3	44.3	6.85
7	100	46.6	6.1	52.7	7.64
7	125	61.2	7	68.2	6.39
7	150	50.3	8.1	58.4	3.85
10	50	41.6	17.5	59.1	7.69
10	75	34.2	14.6	48.8	6.02
10	100	35.1	12.1	47.2	5.9
10	125	27.5	12.4	39.9	3.27
10	150	31.1	12.7	43.8	2.86
CV (%)		40.8	10.2	51	5.8
	Depth	0.9	0.11	1.02	0.34
	Frequency	28.06	6.13	5.97	2.5
LSD (5%)	Frequency*Depth	5.38	0.26	7.56	0.8

Table 6. Effect of irrigation depth and frequency on fruit weight, marketable yield unmarketable yield, total yield and water productivity at Rib

F	D	MY (t ha^{-1})	UMY	TY	WP	Treatment		FW weight
7	50	32.01	5.03	34.96	8.2	F	7	43.44
7	75	38.75	3.94	42.76	6.6		10	41.35
7	100	35.8	5.44	41.19	4.58			
7	125	36.53	4.52	40.48	3.7	Depth	50	43.82
7	150	36.45	3.6	40.02	3.1		75	40.45
10	50	34.73	4.62	39.33	8.9		100	42.36
10	75	35.72	3.6	39.46	6.1		125	41.69
10	100	37.48	5.14	42.34	4.8		150	43.67
10	125	38.79	4.94	43.84	4			
10	150	45.51	5.03	50.48	3.9			
CV (%)		12.24	28.2	11.55	6			8.35
LSD (5%)	D	3.77	ns	3.97	0.8			1.86
	F	2.38	ns	2.51	0.6			ns
	D*F	5.41	ns	6.61	1.7			ns

Where: MY = marketable yield (t ha^{-1}), UMY = unmarketable yield (t ha^{-1}), TY = total yield (t ha^{-1}), WP = water productivity (kg m^{-3})

Total fruit yield

Total fruit yield of tomato had a positive response for irrigation frequency and depth as well as for interaction $p<0.05$.the interaction effect of irrigation frequency and depth had significance effect on total fruit yield of tomato. The lowest (39.9 t ha^{-1}) and the highest (68.2 t ha-1) total yield of tomato were obtained at 125%CWR at 10 and 7 day interval respectively at Koga. The lowest (34.96 t ha^{-1}) and the highest (50.48 t ha^{-1}) marketable yield of tomato were obtained for 50%CWR at 7 day and 150%CWR at 10 day irrigation interval, respectively at Rib. The results showed that with a decrease in the depth of irrigation, there was a decrease in total fruit yield in tomato due to reduced uptake of water. The result of this study in line with that of Muchovej et al. (2008) who reported that high quality and yield of vegetable crops are directly associated with proper water management. Fekadu et al (2006) also found that the fresh fruit yields of tomato were reduced under deficit irrigation level. Generally, total yield of tomato at Koga and Rib showed a similar trend with marketable yield.

Water productivity

Interaction effects between irrigation schedule and depth had significantly influence on water productivity of tomato ($P \leq 0.05$, Table 5&6). Irrigation regimes have positive and highly significant effect on water productivity of tomato. The lowest (2.86 kg m^{-3}) and the highest (7.69 kg/ m3) water productivity of tomato were obtained for 150% and 50%CWR at 10 day irrigation interval, respectively at Koga. The result is in line with the finding of Solomon et al (2014), who reported Application of 14mm depth of irrigation (i.e. 75% of Cropwat generated depth) at 11 days interval gave the highest water productivity of 6.18 kg m-3 around Jari, eastern Amhara. The lowest (3.9 kg m^{-3}) and the highest (8.9 kg m^{-3}) water productivity of tomato were obtained for 150% and 50%CWR at 10 day irrigation interval, respectively at Rib. The water productivity, however, decreased with increasing irrigations depth both at 7 and 10 days irrigation interval.

Conclusion and recommendations

The effects of irrigation regime were assessed by examining their effects on yield and water productivity of tomato. The result of current study revealed that irrigation scheduling and depth had a significant effect on total fruit yield and water productivity in both irrigation schemes. Marketable and total fruit yield of tomato increased with increase in irrigation depth at 7 and 10 day interval at Koga and Rib irrigation scheme respectively. At Koga, 68.2 and t ha^{-1} and 6.38 kg m^{-3}, maximum yield and water productivity was achieved at 125% CWR at 7 day interval. In Koga area, a total of 18 irrigations were applied during the growing season. Application of 150%CWR at 10 days interval gave significantly better marketable yield, total yield, water productivity and bulb weight as compared to the optimum level. In Rib area a total of 12 irrigations afterwards were applied during the growing season. Hence from the foregoing statistical analysis results, if irrigation regime is aimed at maximizing yields per unit of irrigated area, 150%CWR at 10 day interval is recommended for Rib and similar agro ecology and 125%CWR at 7 day interval is recommended for Koga and similar agro ecology.

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Effect of variable irrigation regime on yield and water productivity of pepper (capsicum annum) in western Amhara, Ethiopia

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Abstract

Field experiments were conducted at Koga and Rib irrigation schemes during 2010 to 2012 to determine the optimal irrigation regime for pepper. The treatments were arranged in a factorial combination of two irrigation intervals (7 and 10 days) and five irrigation depths (50, 75, 100, 125 and 150%) laid out in a randomized complete block design with three replications. Agronomic data, such as pod length, marketable and total yield were collected and analyzed using SAS 9 software and significant treatment means were separated using least significant difference at 5%. Irrigation frequency showed significant effect on pod yield than irrigation depth and their interaction also showed significant effect on total yield and water productivity. At Koga, application of 75% irrigation water amount (irrigation depth) at 7 days interval gave 8.2 t ha^{-1} marketable yield, 8.35 t ha^{-1} total yield, and 1.77 kg m^{-3} water productivity. While at Rib, application of 50% crop water requirement at 7 days irrigation interval gave 20.68 t ha^{-1} marketable yield and 5.69 kg m^{-3} water productivity. Net irrigation water requirement of pepper was 421.3 mm at Koga and 310 mm at Rib corresponding to 17 irrigations. Therefore, for optimum yield and water productivity, pepper can be irrigated with 75% CWR every seven days at Koga and with 50%CWR every seven days interval at Rib.

Key words: Irrigation regime, Koga, pepper, Rib, scheme

Introduction

Recently precision agriculture in humid areas is already being used to increase yield and water productivity thereby making irrigation feasible (DeJonge and Kaleita, 2006). If there is proper irrigation management i.e., schedule irrigation timing and amounts based on accurate crop water use, irrigation has a positive effect on yield provided planted crops are not stressed before water application. In countries with large rainfall amounts over a period of years and within the same year, temporal variation in storm frequency do not always coincide with crop needs at critical periods. Hence, irrigation scheduling remains one of the critical needs for efficient water management in crop production in humid areas (Thomas et al., 2004). Irrigation scheduling and yield have positive correlation (Al-Jamal et al., 1999; Rockstrom, 2001). The relationship between the total quantity of water applied and the yield of a specific crop is a complicated one which Upton (1996) agrees may vary in frequency and amount. Problems associated with the sequential nature of irrigation water inputs, stem from the fact that crop-yield response depend on the timing and adequacy of individual water application. Appling optimum amount at right time as well as at critical growth stages have crucial impact (Upton, 1996; Michael, 1998). Thus, to attain stable crop yields with unpredictable storm frequency variability, irrigation scheduling is often necessary.

In Ethiopia, the population is growing rapidly and is expected to continue growing, which inevitably lead to increased food demand. To maintain self-sufficiency in food supply, one viable option is to raise the production and productivity per unit of land through irrigation. Proper amount and timing of irrigation water applications is a crucial decision for a farm manager to meet the water needs of the crop to prevent yield loss and maximize the irrigation water use efficiency resulting in beneficial use and conservation of the local water resources (Richard et.al 1998).

In Ethiopia capsicum is the leading crop among vegetable growing in terms of area coverage (CSA 2012/13). Average yield of capsicum was very low while the world average yield of capsicum is 16.85 qt/ha for dry period and 162.8 qt/ha for green pod (FAOSTAT 2012).Several factors are responsible for this discrepancy; among which irrigation water management are the foremost factors (Fekadu and Dandena, 2006). Many investigations have been carried out worldwide regarding the effects of irrigation regime on yield of vegetables (Samson and

Ketema, 2007). However, most of these studies assessed the effect of reduced water stress; irrespective of appropriate irrigation regime.

Capsicum planted under irrigation condition cannot withstand long dry period. Under such conditions, the plant may shade flowers and drop fruits. Irrigation at an interval of every other day for the first three weeks and 5-7 days then after depending on soil growing conditions can provide good yield. Irrigating late in the afternoon and over irrigating is not advisable in order to control root-rot disease (Asfaw et al., 2015).However in Ethiopia particularly in Amhara region irrigation regime under which crop water requirement is optimum has not yet been established for green pod peppers. Hence, the objectives of this study were to determine the crop water requirement and irrigation schedule of pepper.

Materials and methods

Site description

The trial was conducted during 2010 and 2012 at Koga and Rib irrigation schemes, west Amhara, Ethiopia. Koga irrigation scheme is located in Mecha District; 41 kilometres from Bahir Dar on the way to Addis Abeba via Debremarkos (37°7'29.721''Easting and 11°20'57.859''Northing and at an altitude of 1953 m a.s.l). The average annual rainfall of the area is about 1118 mm. The mean maximum and minimum temperatures are 26.8^{o}C and 9.7^{o}C respectively. The soil type is generally Nitisols and clay in its nature. The soil has low available phosphorous (6.12 ppm), medium nitrogen 0.21% strongly acidic soil reaction (pH =) 4.6. The field capacity (FC) and permanent wilting point of the study area were 32 (%w/w) and 18 (%w/w); respectively

Rib irrigation site is located in Fogera District, 60 kilometers from Bahir Dar in the way to Gondar road (37°25' to 37°58' Easting and 11°44' to 12°03' Northing and at an altitude of 1774 m a.s.l). It receives an average of 1400 mm rainfall annually. The mean daily maximum and minimum temperatures of the study area were 30°c and 11.5°c. The area is characterized as mild altitude agro-ecology. The soil at the experimental site is Fluvisols (an alluvial deposit). The soil has high available phosphorous (36.71ppm), very low nitrogen content (0.003%), high cation exchange capacity (CEC = 33.0 cmolc kg^{-1} soil) and neutral soil reaction (pH = 6.7). The field capacity (FC) and permanent wilting point (PWP) of the study area were 59.25 (%w/w) and 21 (%w/w) respectively.

Methods

CROPWAT 8.0 for windows was used to estimate daily reference crop evapotranspiration and generate the crop water requirement and the irrigation schedule for pepper in the study areas (Table 1 and 2). Calculations of the crop water requirements and irrigation schedule were carried out taking inputs of climate, soil and crop data. In order to estimate the climatic data (wind speed, sunshine hours, relative humidity, minimum and maximum temperature) LOCCLIM, local climate estimator software (FAO, 1992) were used for both at Koga and Rib where there is no class A meteorological stations. The estimator uses real mean values from the nearest neighbouring stations and it interpolated and generated climatic data values for the study site. Based on the technology we use, we assume 70 % application efficiency both at Rib and Koga, and then the gross water requirement was calculated. The demand for water during the plants growing season varies from one growth stage to another. Values of potential evapotranspiration (ET_0) estimated were adjusted for actual crop ET. Table 3 and 4 shows CROPWAT 8 Windows tables for ET.

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April	13.3	29.8	43	1	8.8	23.1	3.98
May	14.4	28.9	53	1	8.6	22.4	4.03
June	14.0	26.6	67	1	6.7	19.2	3.59
July	13.7	24.0	76	1	4.4	15.9	3.01
August	13.6	24.0	77	1	4.3	15.9	3.00
September	12.9	25.1	72	1	5.9	18.2	3.30
October	12.5	26.2	63	1	9.0	21.9	3.70
November	10.4	26.3	57	1	9.5	21.2	3.35
December	7.9	26.2	54	1	10.0	21	3.11
Average	11.8	26.8	58	1	8	20.5	3.46

Table 2. Climate and ETo data of Rib

Month	Min Temp °C	Max Temp °C	Humidity %	Wind Km day^{-1}	Sun hours	Rad MJ m^{-2}day^{-1}	ETo Mm day^{-1}
January	4.6	30.5	54	2	9.2	20.3	3.12
February	6.3	33.0	51	2	10.0	22.9	3.73
March	8.0	33.0	49	2	10.0	24.4	4.17
April	9.0	32.7	51	2	8.5	22.6	4.07
May	10.0	31.6	65	2	6.7	19.6	3.76
June	10.4	28.5	80	2	5.4	17.4	3.41
July	9.8	25.0	85	1	1.6	11.8	2.39
August	10.1	25.5	86	1	6.7	19.6	3.57
September	9.8	27.0	82	1	9.0	22.9	4.08
October	7.4	29.0	76	2	10.0	23.2	3.99
November	6.7	30.0	69	2	10.0	21.6	3.55
December	5.6	30.0	61	1	7.4	17.3	2.81
Average	8.1	29.6	67	2	7.9	20.3	3.56

Table 3. Crop water and irrigation requirements for pepper at Koga

Month	Decade	Stage	Kc coeff	ETc mm day^{-1}	ETc mm dec^{-1}	Eff rain mm dec^{-1}	Irr. Req. mm dec^{-1}
Dec	3	Initial	0.6	2.02	8.1	0	8.1
Jan	1	Initial	0.6	2.06	20.6	0	20.6
Jan	2	Initial	0.6	2.1	21	0	21
Jan	3	Development	0.62	2.31	25.4	0	25.4
Feb	1	Development	0.75	2.98	29.8	0	29.8
Feb	2	Development	0.9	3.77	37.7	0	37.7
Feb	3	Development	1.03	4.46	35.7	0	35.7
Mar	1	Mid	1.11	4.95	49.5	0	49.5
Mar	2	Mid	1.11	5.1	51	0	51.0
Mar	3	Mid	1.11	5.22	57.4	0.1	57.3
Apr	1	Mid	1.11	5.34	53.4	1.8	51.6
Apr	2	Late	1.08	5.29	52.9	2.6	50.2
Apr	3	Late	1.01	4.87	48.7	3.9	44.8
May	1	Late	0.96	4.68	4.7	0.2	4.7
					495.8	8.5	487.4

Where: Coef = coefficient, Irr.req.= irrigation requirement

Table 4. Crop water and irrigation requirements for pepper at Rib

Month	Decade	Stage	Kc coeff	ETc mm day^{-1}	ETc mm dec^{-1}	Eff rain mm dec^{-1}	Irr. Req. mm dec^{-1}
Dec	3	Initial	0.60	1.87	07.5	0	07.5
		Initial	0.60	1.87	18.7	0	18.7
Jan	2	Initial	0.60	1.88	18.8	0	18.8
Jan	3	Development	0.62	2.00	22.0	0	22.0
Feb	1	Development	0.73	2.45	24.5	0	24.5
Feb	2	Development	0.85	2.95	29.5	0	29.5
Feb	3	Development	0.96	3.44	27.5	0	27.5
Mar	1	Mid	1.02	3.78	37.8	0	37.8
Mar	2	Mid	1.03	3.89	38.9	0	38.9
Mar	3	Mid	1.03	3.95	43.5	0.1	43.4
Apr	1	Mid	1.03	4.02	40.2	1.8	38.4
Apr	2	Late	0.99	3.94	39.4	2.6	36.8
Apr	3	Late	0.91	3.65	36.5	3.9	32.6
May	1	Late	0.87	3.49	03.5	0.2	03.5
					388.3	8.5	379.9

Treatment setup

The on-farm trial was conducted in the dry season with ten different treatments in both location at Rib and Koga. Two irrigation intervals i.e. 7 and 10 days and five irrigation interval (50, 75,100,125 and 150 % CWR) of variable depths at four growth stages are selected based on CROPWAT 8.0. Thus the following treatments were set and evaluated for verification of the Cropwat prediction with field experimentation:

1. 50%CWR at 7 day interval
2. 75%CWR at 7 day interval
3. 100%CWR at 7 day interval
4. 125%CWR at 7 day interval
5. 150%CWR at 7 day interval
6. 50%CWR at 10 day interval
7. 75%CWR at 10 day interval
8. 100%CWR at 10 day interval
9. 125%CWR at 10 day interval
10. 150%CWR at 10 day interval

The treatments were arranged in a randomized complete block design (RCBD) replicated three times. The experiment was carried out from December to April. The test crop was pepper with variety Marco Fana. The plot size was 2.8 m by 6 m plot at Koga and 2.8m by 3m at Rib. Spacing between treatments was 1m while between block was 1.5m. Spacing between rows and plants were 0.7cm and 0.3cm; respectively. Di-ammonium phosphate (DAP) fertilizer was applied at a rate of 200 kg ha^{-1} at planting while 100 kg urea ha^{-1} was applied half at planting and the remaining half at 45 days after planting. Stand count, total yield, marketable yield, pod length, pod weight, and unmarketable yield were collected. Water productivity was calculated as the ratio of marketable yield to amount of water consumed based on Arega (2003).

Data analysis

The means of the above parameters were subjected to analysis of variance (ANOVA) using SAS version 9 computer software. Mean comparison was done by using least significant difference test at 5% probability level.

Results and discussion

ANOVA (showed that agronomic data such as marketable yield, unmarketable yield, and total yield was not show significant difference over year, year by frequency and depth. At Koga, the response of most biological parameters to the interaction of irrigation frequency and depth was significant at ($p< 0.05$). At Rib, the response of most biological parameters to irrigation depth and irrigation frequency was non-significant at ($p< 0.05$).

Pod length

Pod length showed significant response for irrigation depth at Rib ($p<0.05$). The interaction of irrigation depth and frequency was not significant at Rib while did for Koga ($p<0.05$). The lowest (9.33cm) and the highest (10.35) pod length of pepper were obtained for 75% and 150% crop water requirements; respectively. The result was in harmony with Habtamu et al., (2014). In his report the average pod length ranged between 9.6-10.05 cent meters.

Pod weight

Average pod weight showed significant response for irrigation depth at Rib ($p<0.05$). The lowest (9.9gm) and the highest (11.5) average pod weight of pepper were obtained for 50% and 150% crop water requirements; respectively. The result was in harmony with Habtamu et al., (2014) who reported average pod weight in the range of 12-17.5 gram.

Marketable yield

At Koga, irrigation frequency and depth showed significant effect on marketable pod yield of pepper ($P < 0.05$, Table 5 and 6). The lowest (3.7 t ha^{-1}) and the highest (8.6 t ha^{-1}) marketable pod yield of pepper were obtained at 75%CWR with 10 days interval and at 125%CWR with 7 days irrigation interval; respectively. Marketable yield of pepper increased when frequent irrigation was given than longer durations. Even if marketable yield was not respond to irrigation depth; yield decrease with increase of water level at 10 days interval. However, at 7 days interval irrigation depth did not show any trend. This implies much higher and lower irrigation depth can adversely affect marketable yield through the development of physiological disorder such as aeration and create favorable environment for root rot and cut worm.

The yield obtained from this experiment was very low might be due to the occurrence of root rot, wilt and cut worm (Table 6). The production was low compared to other areas as well as world average yield of green pod which is 16.28 t ha^{-1} (FAOSTAT 2012); this might be due to poor soil fertility and acidification at Koga. Pepper is very sensitive to soil acidity and its suitable pH ranges between 6 to 7 while at Koga it is about 4.6 which is below the critical level.

The soil organic matter and available phosphorus are also very low at the study site based on Clements and McGowen (1994) category.

At Rib, irrigation frequency showed significant effect on marketable pod yield of pepper ($p < 0.05$, Table 7). The lowest (17.31 t ha^{-1}) and the highest (20.68 t ha^{-1}) marketable pod yield of pepper were obtained for 10 and 7 days irrigation interval; respectively. The effect of irrigation levels on the marketable pod yield was not significant at ($p < 0.05$, Table7). The lowest marketable yields (17.83 t ha^{-1}) was recorded at 50% CWR, reaching maximum (19.91 t ha^{-1}) at 125% CWR. Marketable yield of pepper increased when frequent irrigation is given than longer duration. Even if marketable yield was not respond to irrigation depth; yield increase with increase of water level up to 125%CWR. However, further increase in irrigation level had negative effect on marketable yield of pepper.

The total green pod yield of pepper at Rib was much larger than Koga irrigation scheme as well as in line with the world average production of green pod pepper, this might be the soils at Rib are Fluvisols which are deposited from upper catchments and have good nutrient content. The finding was in line with findings of Baye et al. (2010) and Birhanu et al. (2014), where they found a non-significant effect of phosphorus for all agronomic parameters.

Table 5. ANOVA for pod length, marketable, unmarketable, total yield, disease incidence and water productivity at Koga (2010/11 and 2011/12)

Source	Df	Pod (cm)	Marketable yield (t ha^{-1})	Unmarketable yield (t ha^{-1})	Total yield (t ha^{-1})	Disease incidence (%)	Water Productivity (kg m^{-3})
Year(Y)	1	9.10 ns	0.63 ns	0.03 ns	0.37 ns	0.93 ns	0.01 ns
Rep (R)	2	2.10ns	1.58 ns	0.1 ns	2.4 ns	61.6 ns	0.01 ns
Freq.(F)	1	37.20 **	195**	7.01 **	128.3 **	4208 **	5.28 **
Depth (D)	4	6.97 ns	0.34 ns	0.48 **	1.14 ns	258 ns	0.87 **
Y*F*D	13	2.00 ns	2.4 ns	0.23 ns	2.87 ns	162 ns	0.07 ns
R*F	2	0.18 ns	0.2 ns	0.16 ns	0.55 ns	105 ns	0.004 ns
F*D	8	18.28 **	6.43 **	0.34 *	9.64 **	585.5 *	0.23 **
Error	28	3.87	1.34 **	0.1	1.64	144	0.05
CV(%)		20.98	19.08	73.1	19.7	51.7	19.7

*Where: Df = Degree of freedom, ns not significant * significant and ** highly significant*

Table 6. Marketable yield, total yield, disease incidence and water productivity analysis result of Koga

Frequency	Depth	Marketable yield (t ha^{-1})	Total (t ha^{-1})	Disease Incidence (%)	Water Productivity (kg m^{-3})
7	50	6.8	6.96	19.6	1.53
7	75	8.2	8.35	16.2	1.77
7	100	7.5	7.60	16.2	1.55
7	125	8.6	8.67	10	1.3
7	150	8.2	8.26	12.1	0.97
10	50	5.6	7.00	12.9	1.32
10	75	3.7	4.30	22	0.81
10	100	4.2	5.00	30.4	0.87
10	125	3.9	4.50	35.4	0.64
10	150	3.8	4.27	37	0.52

Table 7. Pod weight, pod length, marketable yield, total yield and water productivity analysis result of Rib

					Pod		Marketable yield (t/ha)
Frequency	Depth	Productivity (kg/ m3)			Weight (gm)	Length (cm)	
7	50	5.69	F	7	10.9	9.73	20.68
7	75	4.14		10	10.1	9.69	17.31
7	100	3.25					
7	125	2.58	D	50	9.9	9.64	17.83
7	150	2.21		75	10.1	9.33	18.72
10	50	5.12		100	10	9.4	19.17
10	75	3.43		125	11	9.83	19.91
10	100	2.56		150	11.5	10.35	19.36
10	125	2.25					
10	150	1.71					
		6.8			12.5	7.7	14.9
	D	1.03			1.083	0.622	ns
	F	0.87			0.685	ns	1.583
	D*F	1.7			ns	ns	ns

Total pod yield

Irrigation frequency had a highly significant effect ($P < 0.01$) on total pod yield of pepper. Irrigation levels had not significantly affected the total pod yield of pepper ($p < 0.05$, Table 5 and 6). Interaction effect of irrigation frequency and depth was significance on total pod yield of pepper. The lowest total pod yield of pepper (4.27 t ha^{-1}) was obtained at 10 day irrigation interval with 150% crop water requirement, while the highest pod yield (8.67 t ha^{-1}) was obtained at 7 day irrigation interval combined with 75% crop water requirement. The low pod yield result might be due to the occurrence of disease. The result was in line with the finding of Habtamu et al. (2014) who reported a pod yield of 6.4 t h^{-1} with irrigation and 8.97 t h^{-1} with rainfed condition at Woramit (Bahir dar). The average pod yield of pepper at Koga was about half of the world average for the probably due to the interaction effect of soil and water regime that led to high disease as reported by Asfaw et al. (2015).

Water productivity

The response of water productivity at Koga to irrigation regime was highly significantly at ($p \leq 0.01$). The lowest (0.52 kg/ m3) and the highest (1.77 kg/ m3) water productivity were obtained at 150%CWR with 10 day irrigation interval and 125%CWR with 7 day irrigation interval ; respectively. At Rib, the response of water productivity to irrigation regime was also highly significantly ($P \leq 0.01$). The lowest (1.71 kg/ m3) and the highest (5.69 kg/ m3) water productivity were obtained from 150%CWR with 10 day and 50%CWR with 7 day irrigation interval; respectively. Generally water productivity decreased with increasing irrigation depth for both locations. The finding was line with Kebede (2003) and Samson and Ketema (2007). They reported that water productivity decreased with increased irrigation depth.

Conclusion and recommendation

The effect of irrigation regime was assessed by examining their effects on yield and water productivity of pepper. The result of current study revealed that irrigation frequency and depth significantly affected marketable yield, total yield and water productivity at Koga and Rib irrigation schemes. Marketable yield responded only for irrigation frequency at Rib irrigation scheme. Marketable, total bulb yield and water productivity increased with increased irrigation frequency/shorten duration from 10 to 7). At Koga, 50%CWR at 7day interval gave 8.35 t ha^{-1}

and 1.77 kg/ m3 that is reasonable yield and water productivity; respectively. While at Rib, 50%CWR at 7 day interval, 20.68 t ha^{-1} and 5.69 kg/ m3 yield and water productivity were achieved respectively. Hence, if irrigation scheduling is aimed at maximizing yields per unit of irrigated area; 50%CWR with 7 day interval recommended for Rib and 125% CWR with 7 day interval recommended for Koga and similar agro ecology. However, if the scheduling objective is to maximize yield per unit depth of water applied, 75%CWR with 7 day interval is recommended for Koga and similar agro ecology. For Rib and similar agro-ecologies 50%CWR with 7 day interval recommended.

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Effect of variable irrigation regime on yield and water productivity of potato at Koga irrigation scheme

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Abstract

In Ethiopia, Irrigation water management is challenged by improper water application. Field experiment was therefore conducted to investigate the effect of irrigation regime on yield and water productivity of potato at Koga irrigation scheme during 2010 and 2012 irrigation seasons. The treatments contained a factorial combination of two irrigation intervals (7and 10 days) with five irrigation depths (50, 75,100,125 and 150% of the crop water requirement) and laid down in a randomized complete block design with three replications. Stand count, marketable tuber yield, total tuber yield and tuber number were collected and analyzed using SAS 9.0 and significant treatment mean differences were separated using least significant difference at 5%. The results depicted that irrigation frequency had significant effect on tuber yield than irrigation depth. The interaction effect of irrigation frequency and depth was significant on total tuber yield and water productivity. Application of 100 %CWR irrigation depth at 7 days irrigation interval gave 10.84 t ha^{-1} marketable yield, 13.2 t ha^{-1} total tuber yield and 1.5-1.8 kg m^{-3} water productivity. Irrigation water requirement of potato was 540.5 mm that corresponds to 17 irrigations throughout the growing season. Therefore, in order to attain an optimum yield and water productivity, at Koga and similar agro ecology areas potato should be irrigated with 100%CWR at 7 days interval.

Key words: Irrigation regime, Koga, marketable yield, potato, tuber yield,

Introduction

Potato is one of the staples crop grown in Ethiopia. The highest production is in the northwest, central, south and southeast parts of the country with sufficient moisture, favourable day to night temperature regimes, and irrigated production potentials. In 2015/16, more than 5 million smallholders were engaged in potato production resulted in a 172% increase compared to 2001/02. Over 3.66 million MT of potato was produced in 2015/16, a 540% increase compared to 2001/02 (CSA, 2002, CSA, 2016). Total area allocated to potato also expanded by over 9% from 0.16 million hectares in 2001/02 to about 0.30 million hectare in 2015/6 (CSA, 2016); an 87.5% increase. Similarly, the average potato yield showed a 122.3% increase from 5.7 t ha^{-1} in 2001/02 to 12.67 t ha^{-1} in 2015/16. The adoption and coverage of 25.2% of the total potato area in the country with improved varieties might have partly contributed to the witnessed productivity gain (Labarta et al., 2012).

The actual potato yield in Ethiopia ranges between 8 and 12 t ha^{-1}; slightly below the average of Africa (10 t ha^{-1}). In 2009/10, Ethiopia achieved yield between 11-12 t ha^{-1}. Nevertheless the yields are below that of Sudan (17 t ha^{-1}) and Egypt (26t ha^{-1}), (Anton et al., 2012). Several factors are responsible for this discrepancy, among which irrigation water management is the most limiting (Fekadu and Dandena, 2006). Many investigations have been carried out worldwide regarding the effects of irrigation regime on yield of potato (Menelik et al., 2013). However, most of these studies assessed the effect of reduced water stress (irrespective of appropriate irrigation scheduling to the entire growth stage off potato).

Potato irrigation management is to minimize soil water fluctuations and maintain available soil water within the optimum range of 65-85 percent. Irrigation systems best suited to this task are those that are capable of light, uniform, and frequent water applications. An effective irrigation management program must include regular quantitative monitoring of soil water availability, and scheduling irrigations according to crop water use, soil water holding capacity and crop-rooting depth. Potato is more sensitive to water stress than most other crops, have relatively shallow root systems, and are commonly grown on coarse-textured soils. These conditions dictate utilization of a quantitative potato irrigation management program for consistent and optimum economic return. Potato is the popular vegetable grown under irrigation in most of the traditional and the recent modern irrigation schemes in Amhara Region. However, the largest production of potato is not supported with improved water management practices to improve its productivity. There is lack of location specific research results of how much water and when to irrigate potato. Hence, the objectives of this study were to determine the crop water requirement and irrigation schedule on the yield of potato and water productivity using CROPWAT computer model and with field experiments at Koga irrigation scheme.

Materials and methods

Site description

The research was conducted during 2010 and 2012 cropping season at Koga irrigation schemes, west Amhara, Ethiopia. Koga irrigation scheme is located in Mecha district; 41 kilometres from Bahir Dar on the way to Addis Ababa via Debremarkos (37°7'29.721" Easting and 11°20'57.859" Northing and at an altitude of 1953 m a.s.l). The average annual rainfall of the area is about 1118 mm. The mean maximum and minimum temperatures are 26.8^{o}C and 9.7^{o}C respectively. The soil type is generally light clay Nitisols. The soil has low available phosphorous (6.12 ppm), medium nitrogen (0.21%) and strongly acidic soil reaction (pH = 4.6). The field capacity (FC) and permanent wilting point of the study area were 32 (%w/w) and 18 (%w/w); respectively.

Methods

CROPWAT 8.0 for Windows was used to estimate daily reference crop evapotranspiration and generate the crop water requirement and the irrigation schedule for potato (Table 1 and 2). Calculations of the crop water requirements and irrigation schedule were carried out taking climate, soil and crop data inputs. In order to estimate the climatic data (wind speed, sunshine hours, relative humidity, minimum and maximum temperature), LOCCLIM, local climate estimator software (FAO, 1992) was used. The estimator uses real mean values from the nearest neighbouring meteorology stations and it interpolated and generated climatic data values for the study site. Based on the technology we used, we assumed 70% application efficiency, and then the gross water requirement was calculated. The demand for water during the growing season varies from one growth stage to another. Values of potential evapotranspiration (ET_O) estimated were adjusted for actual crop ET. Table 3 and 4 show CROPWAT 8 Windows tables for ET.

Principally, CropWat outputs generated by default were used to identify irrigation timing when 100% of readily available moisture occurs and application depth where 100% of readily available moisture status is attained. To verify the CropWat output, field experiments were carried out for two consecutive years.

Table 1. Climate and ETo data of Koga

Month	Min Temp °C	Max Temp °C	Humidity %	Wind Km day^{-1}	Sun hours	Rad MJm^{-2}day^{-1}	ETo Mmday^{-1}
January	7.5	26.5	51	1	9.8	21.3	3.13
February	9.2	28	45	1	9.8	22.8	3.48
March	12	29.5	42	1	9.1	23.1	3.8
April	13.3	29.8	43	1	8.8	23.1	3.98
May	14.4	28.9	53	1	8.6	22.4	4.03
June	14	26.6	67	1	6.7	19.2	3.59
July	13.7	24	76	1	4.4	15.9	3.01
August	13.6	24	77	1	4.3	15.9	3
September	12.9	25.1	72	1	5.9	18.2	3.3
October	12.5	26.2	63	1	9	21.9	3.7
November	10.4	26.3	57	1	9.5	21.2	3.35
December	7.9	26.2	54	1	10	21	3.11
Average	11.8	26.8	58	1	8	20.5	3.46

Table 2. Crop water requirements of potato at Koga

Month	Decade	Stage	Kc Coeff.	ETc Mmday^{-1}	ETc Mm dec^{-1}	Eff rain Mm dec^{-1}	Irr. Req. Mm dec^{-1}
Dec	2	Initial	0.4	1.24	3.7	0	3.7
Dec	3	Initial	0.4	1.25	13.7	0	13.7
Jan	1	Development	0.42	1.33	13.3	0	13.2
Jan	2	Development	0.63	1.98	19.8	0	19.8
Jan	3	Development	0.89	2.89	31.8	0	31.8
Feb	1	Mid	1.11	3.73	37.3	0	37.3
Feb	2	Mid	1.13	3.95	39.5	0	39.5
Feb	3	Mid	1.13	4.07	32.5	0.1	32.4
Mar	1	Mid	1.13	4.19	41.9	2	39.9
Mar	2	Late	1.11	4.22	42.2	3	39.2
Mar	3	Late	0.78	3.01	33.2	4.8	28.4
Apr	1	Late	0.45	1.76	10.5	4	7.2
					319.4	14	306.1

Treatment setup

On-farm experiment was conducted in the dry season (December to April) with ten different treatments. Two irrigation intervals (7 and 10 days) and five irrigation levels (50, 75,100,125 and 150% CWR depths) at four growth stages were selected based on CROPWAT 8.0. Thus the following treatments were set and evaluated for verification of the CropWat prediction with field experimentation:

1. 50%CWR at 7 day interval
2. 75%CWR at 7 day interval
3. 100%CWR at 7 day interval
4. 125%CWR at 7 day interval
5. 150%CWR at 7 day interval
6. 50%CWR at 10 day interval
7. 75%CWR at 10 day interval
8. 100%CWR at 10 day interval
9. 125%CWR at 10 day interval
10. 150%CWR at 10 day interval

The treatments were arranged in factorial experiment with randomized complete block design (RCBD) with three replications. The plot size was 3m by 6 m. Spacing between treatments and block were 1m and 1.5m respectively. The space between plants was 0.3m and 0.75m between rows was used. Jalenie was the variety used. Di-ammonium phosphate (DAP) fertilizer was applied at a rate of 150 kg ha^{-1} at planting while 117 kg urea ha^{-1} was applied half at planting and the remaining half 45 days after planting. Total tuber yield, marketable yield and unmarketable yield were collected. Water productivity was calculated as the ratio of marketable yield to amount of water consumed based on Arega (2003).

Data Analysis

Collected agronomic data were analyzed using SAS 9.0 statistical software and means were separated using least significant difference at 5% significance level.

Results and discussion

The finding of the research showed that there was significant effect of frequency on tuber yield, marketable yield, number while for other parameters there was insignificant difference $p<0.05$ between treatments (Table 5 and 6).

Tuber number

Irrigation frequency showed a highly significant effect on total tuber number of potato $p<0.05$, while it was insignificant for irrigation levels and for the interaction .This result suggests that total tuber number can be controlled more effectively by irrigation frequency than irrigation depth. The total tuber number was significantly reduced from 141 to 106 when the irrigation frequency increased from 10 to 7 days irrigation interval.

Marketable tuber Yield

Irrigation frequency showed a highly significant ($P < 0.001$) effect on marketable tuber yield of potato. The lowest (4.62 t ha^{-1}) and the highest (10.84 t ha^{-1}) marketable tuber yield of potato were obtained for 10 and 7 days irrigation interval; respectively. The effect of irrigation depth on the marketable tuber yield was not significant (Table 5 and 6). The lowest marketable yield (6.58 t ha-1) was recorded from 75% CWR, and reaching maximum (8.74 t ha^{-1}) from 150% CWR. Marketable yield of potato increased when with frequent irrigation than when it was applied after longer days. The result was in line with Niguse et al., (2011) that increasing the level of frequency significantly increases marketable tuber yields. However, tested varieties showed less mean performance than varieties tested elsewhere; may be related to the low pH of the soil. Soil pH is an important factor contributing to the overall potato yield and marketable tuber grades. According to Havlin et al., (1999), the optimum soil pH for potato is 5-5.5 while at Koga it is about 4.63. Marketable yield of potato showed positive response up to 100% CWR irrigation depth. Excess water in the soil decreases the oxygen diffusion rate in the root zone (Wan and Kang, 2006) affecting crop yield negatively.

Unmarketable tuber yield

Irrigation frequency showed a highly significant effect on unmarketable tuber yield of potato ($p< 0.05$), while insignificant for irrigation levels and for interaction .This result suggested that unmarketable tuber yield could be managed more effectively by irrigation frequency than irrigation depth. The unmarketable tuber yield was significantly reduced from 3.04 to 2.3 t ha^{-1} when the irrigation frequency increased from 10 to 7 days irrigation interval; implied improper irrigation depth and frequency substantially reduce yields by increasing the proportion of rough and misshaped tubers. A widely fluctuating soil water contents helps for developing tuber defects (Serhat and Abdurrahim, 2009)

Table 5. ANOVA for marketable, unmarketable, total yield and water productivity at Koga

		Mean square				
Sources of variation	Df	Marketable yield	Unmarketable	Tuber number	Total Yield	Water Productivity
Year (Y)	1	0.06ns	2.1ns	1560ns	2.97ns	0.01ns
Replication (R)	2	10.1ns	3.4ns	718ns	1.83ns	0.2ns
Frequency (F)	1	579.9 **	6.8*	18375**	460.7**	13.7**
Depth (D)	4	10.1ns	0.07ns	287ns	9.2ns	1**
Y*F*D	13	7.3ns	1.7ns	350ns	6.4ns	0.2ns
R*F	2	3.4ns	1.2ns	345ns	0.81ns	0.05ns
F*D	8	3.4ns	2.3ns	1049ns	9.8ns	0.3ns
Error	28	4.7	0.97	857	5.58	0.13
CV (%)		28.1	36.5	23.69	22.6	27.2

*Where: Df = Degree of freedom, ns not significant * significant and ** highly significant*

Table 6. Marketable yield, unmarketable yield, total yield and water productivity analysis results

Factors		Stand count	Marketable yield t ha^{-1}	Un marketable yield t ha^{-1}	Total tuber number/plot	Total Yield t ha^{-1}	Water Productivity kg m^{-3})
Frequency	7	38.6	10.84	2.36	141	13.2	1.8
	10	24.8	4.62	3.04	106	7.67	0.85
Depth	50	30.58	8.08	2.73	129.6	10.8	1.68
	75	33.3	6.58	2.83	123.4	9.4	1.29
	100	31.25	8.3	2.64	126.5	10.9	1.56
	125	31.9	6.96	2.64	116.8	9.6	1.03
	150	31.75	8.74	2.67	121.4	11.4	1.06

Total tuber yield

Irrigation frequency highly and significant affected ($p < 0.001$) total tuber yield. The lowest (7.67 t ha^{-1}) total tuber yield was obtained from 10 day interval while the highest (13.2 t ha^{-1}) was from 7 days interval. Irrigation levels were not significant in affecting the total tuber yield $p<0.05$. The lowest total yield (9.4 t ha^{-1}) was recorded from 75%CWR and the maximum (11.4 t ha^{-1}) from 150%CWR. The interaction effect of irrigation frequency and depth were not significantly affecting the total tuber yield. The low result of the yield might be due to the occurrence of bacterial wilt. Moreover, low soil pH and high soil temperature may attribute to reduce yield. According to Havlin et al., (1999), the optimum pH for potato production is about 5-5.5. Total yield of potato showed positive response up to 100%CWR of irrigation depth. Applying the right depth of irrigation and frequency increased the total tuber yield. The result of this research agrees with the findings of Bowen (2003). However, further increased in the irrigation level beyond 100 %WR adversely affects total tuber yield may be due to the fact that much higher irrigation depth aggravates the development of physiological disorders that reduces total tuber yield.

Water productivity

Interaction effect between irrigation frequency and depth showed a non-significantly affect ($P \leq 0.05$) on the productivity of water. The water productivity decreased with increasing depth of irrigations while it was significantly increased by reducing the irrigation interval from 10 days to 7 days. Increasing the water depth from 50 to 150 % CWR resulted in a decrease of water productivity from 1.68 to 1.03 kg m^{-3}. By reducing irrigation interval from 10 to 7 days water productivity increased from 0.85 to 1.8 kg m^{-3}. Compared with full irrigation, the deficit irrigation treatments saved significant depth of water that led to increase of WUE. Similar findings were by other authors (Liu et al., 2006; Shahnazari et al., 2007; Yirga et al., (2010).

Conclusion and recommendation

The effects of irrigation scheduling were assessed by examining their effects on yield and water productivity of potato. The result of current study revealed that the effect of irrigation frequency was significant on marketable yield, total tuber yield and water productivity at Koga irrigation scheme. Marketable and total tuber yield as well as water productivity increased through reducing irrigation interval while water productivity was reduced with increasing irrigation depth. The average maximum yield (13.2 t ha^{-1}) and high water productivity (1.8 kg m^{-3}) were achieved at 7 days interval. The average maximum water productivity (1.68 kg $m^{-3)}$ was achieved by applying 50%CWR. The net irrigation water requirement was found to be 540.5 mm throughout the growing season. Therefore, based on the findings of this research 100%CWR at 7 days interval is recommended for Koga. However, considering water productivity under water stress condition, 50% CWR at 7 day interval could be an alternative option.

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Response of garlic to nitrogen and phosphorus under irrigation in Lasta district

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Abstract

Crop production under irrigation systems is under pronounced challenges resulted in low yield in Waglasta zone of Amhara region for many reasons among which no or inefficient application of the major nutrients (nitrogen and phosphorus) took considerable share. Hence, a field experiment was conducted to study the effect of nitrogen (N) and phosphorus (P) on the growth and bulb yield of garlic at Lasta district Kechin Abeba irrigation scheme in 2013 and 2015. The treatments were arranged in a factorial combination of three rates of N (0, 46, 92, kg ha^{-1}) and four rates of P (0, 23, 46, 69, kg P_2O_5 ha^{-1}) in a randomized complete block design in three replications. All TSP (phosphorus source) was applied at transplanting whereas urea (nitrogen source) was applied in two splits (half at transplanting and the other half at 45 days after planting). Irrigation water was applied uniformly to all plots in furrow every six days. Agronomic data were collected and analyzed using SAS software and significant treatment means were separated using least significant difference at 5% level of significance. The effect of nitrogen and phosphorus was significant on plant height and bulb yield. Application of 92 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} increased bulb yield by 48.3% compared to the control and was economically dominant over the other treatments. Therefore, application of 92 N and 46 P_2O_5 kg ha^{-1} is an optimum rate for garlic production at Lasta District, Kechin Abeba irrigation scheme and similar agro-ecologies.

Keyword: Bulb yield, Garlic, Nitrogen, Phosphorus

Introduction

Garlic is one of the vegetable crops known worldwide for its production and economic value (Salomon, 2002). It is widely used around the world for its pungent flavor as a seasoning or condiment. It is a fundamental component of dishes in the world including Ethiopia. It is rich in sugar, protein, fat, calcium, potassium, phosphorus, sulfur, iodine, fiber, and silicon in addition to vitamin (Purseglove1, 979). The total area under garlic production is estimated to be over 17965 hectares (CSA, 2014). Many biotic and abiotic factors contribute for the low productivity of garlic in Ethiopia including: declining soil fertility, insufficient and inefficient use of fertilizers, inappropriate agronomic practices, and in adequate pest and disease managements. Chemical fertilizers have been the prime means of enhancing soil fertility in small farm agriculture ((Thangavel et al., 2014). Nitrogen (N) and phosphorus (P) are often referred as the primary macronutrients because of the large quantities they are taken up by plants from the soil relative to other essential nutrients (Marschner, 1995). In order to improve garlic production, proper fertilizer application (type, time and rate) should be considered (Brewster and Butler, 1989). In the study area, garlic is produced as a cash crop and there was no fertilizer recommendation done so far for its production. Therefore, this research was conducted to determine the optimum rate of nitrogen and phosphorus fertilizers for garlic production in KechinAbeba irrigation scheme.

Materials and method

Description of the study site

A field experiment was carried out during 2013 and 2015 under irrigation in Kechin Abeba Lasta district, North Wollo Administrative Zone of the Amhara Region (Figure 1). The site is located 12°35’31.2’’N latitude and 39 ° 04’30’’E longitude. The altitude of the study area is 1856 m.a.s.l.

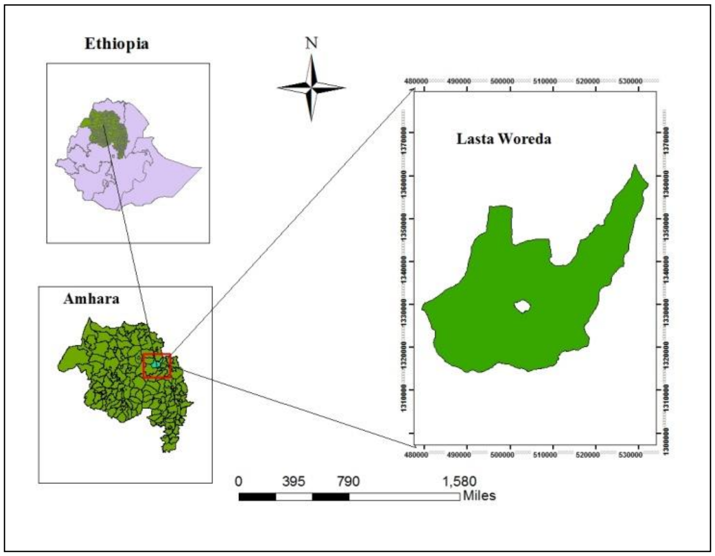

Figure1. Location of the study

Experimental design and treatments

The experiment was conducted using furrow irrigation system. The treatments consisted of three N levels (0, 46, and 92 kg N ha^{-1}) and four P_2O_5 levels (0, 23, 46, and 69 kg P_2O_5 ha^{-1}). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications in a factorial arrangement. The plot size was 6 m^2 (2 m X 3 m) and consisted of 10 rows. Distance between plots and blocks, were 0.5 m and 1 m; respectively while the distances between plants and rows were 0.2 m and 0.10m respectively. Urea and TSP were used as source of nitrogen and phosphorus fertilizers respectively. Nitrogen was applied by splitting: half at transplanting and half after 45 days of transplanting while the whole dose of phosphorus was applied once at transplanting. Agronomic practices such as weeding, cultivation and ridging were done uniformly to all treatments. Water was supplied at 6 days interval using furrow irrigation method. A local variety was used. Plant height, bulb yield, and biomass of garlic were recorded for each plot.

Data analysis

Collected data were subjected to statistical analysis using SAS Statistical Software version 9.0 and treatment mean differences were compared using the Fisher’s least significant differences (LSD) test at 5% level of significance.

Soil analysis

A disturbed composite soil sample was collected from 0-20 cm, air-dried and sieved through 2 mm sieve to determine most nutrients while through 0.5 mm to determine Total Nitrogen and Organic Carbon. Soil pH was determined in H_2O using 1:2.5 soils to solution ratio using a combined glass electrode pH meter (Chopra and Kanwar, 1976). Organic carbon of the soils was determined following the wet digestion method as described by Walkley and Black (1934) while percentage organic matter of the soils was determined by multiplying the percent organic carbon value by 1.724. Total N was analyzed by the Kjeldahal digestion and distillation procedure (Bremner and Mulvaney, 1982), and Particle size distribution was analyzed by hydrometer method.

Partial budget analysis

The partial budget analysis was done to evaluate the economic feasibility of nitrogen and phosphorus application based on the manual developed by CIMMYT (1988). The cost fertilizer, mean price of onion was collected from the district. For the purpose of partial budget analysis (sensitivity analysis), yields were adjusted to 90 of the actual yield collected from the field (reduced by 10%).

Results and discussion

The major soil properties including soil pH, soil organic matter, total nitrogen and soil texture of the study site are discussed below. The pH (pH water) (6.8) was neutral (Tekalign, 1991). The available P (2.6 ppm), soil organic matter (1.01%) and total nitrogen (0.062%) were rated as very low (Tekalign, 1991) and should be improved through organic and inorganic amendments for improved crop growth and yield. The textural class of the study soil was clay loam with 30% sand, 30% silt and 40% clay. The response of the test crop to nitrogen and phosphorus under irrigation was reflected to these major soil chemical and physical properties of the study sites.

Plant height

The result in Table 1 shows that plant height of garlic was not significantly influenced by nitrogen and phosphorus rates. However, relatively higher plant height (54.85 cm) was recorded from 92 N and 69 P_2O_5 ha^{-1} followed by 46 N and 23 kg P_2O_5 ha^{-1} (54.41 cm) while the minimum (45.36 cm) was found from the control plot. The result is in agreement with the findings of (Mulatu et al., 2014) who reported that application of Nitrogen at 46 and 69 kg N and P_2O_5 ha^{-1} increased the plant height significantly. (Adem and Tadesse, 2014) and (Khan et al., 2007) also reported that nitrogen at 46 kg N ha^{-1} increased the plant height significantly**.** The increment in vegetative parameters for garlic with the addition of N had a profound influence on the development of the crop. Application of adequate quantity of nitrogen ensures healthy plant growth that manifests through increasing vigor, size and deeper green color of foliage (Miko, 1999).

Bulb yield

The interaction of nitrogen and phosphorus fertilizers significantly affected the total bulb yield. The maximum bulb yield (7.11 t ha^{-1}) was obtained from plots fertilized with nitrogen and phosphorus at the rate of 92 N 46 P_2O_5 kg ha^{-1} followed by 46 N and 46 P_2O_5 (6.7 t ha^{-1}) (Table

1). However, further increase of nitrogen and phosphorus rates showed a decreasing trend of the bulb yield (Table 2). The minimum average yield (4.8 t ha^{-1}) was obtained from the control plot. This yield increment might be due to the fact that nitrogen supply increase the rate of metabolism that in turn results in a synthesis of more carbohydrate and high bulb yield (Miko, 1999). The result is also in line with the findings of (Farooqui et al., 2009) and (HORE et al., 2014) who reported that application of nitrogen at rate of 92 N kg h^{-1} increased the total bulb yield of garlic.

Table 1. Effects of nitrogen and phosphorus fertilizer application on growth and yield of garlic

Fertilizer (Kg ha^{-1})		Plant height (cm)			Bulb yield (Q ha^{-1})			Biomass yield (Q ha^{-1})		
N	**P_2O_5**	Year-1	Year- 2	Combined	Year-1	Year-2	Combined	Year-1	Year-2	Combined
0	0	47.66	43.40	45.36	57.99	41.87	47.93	67.54	51.45	59.50
46	0	54.40	45.60	50.00	57.63	50.72	54.18	63.26	60.83	62.04
92	0	51.96	47.86	49.91	61.61	57.43	59.52	67.24	69.72	68.48
0	23	48.93	45.13	47.03	52.57	47.91	50.24	65.09	60.47	62.78
46	23	56.56	52.46	54.51	61.55	58.26	59.90	73.14	70.00	71.56
92	23	55.93	51.93	53.93	51.78	68.40	60.09	57.60	83.54	70.56
0	46	47.33	44.06	45.86	54.35	48.43	51.39	63.09	63.22	63.16
46	46	50.10	46.00	48.05	73.96	59.27	66.61	84.78	73.85	79.31
92	46	54.00	53.26	51.96	67.28	74.89	71.09	79.09	86.19	82.64
0	69	47.66	43.60	45.63	54.52	42.50	48.51	62.85	53.54	58.19
46	69	52.43	48.33	50.38	52.58	57.15	54.87	60.68	67.50	64.08
92	69	56.90	52.80	54.85	73.44	58.68	66.06	77.26	72.98	75.12
	LSD (5 %)	10.47	11.66	11.09	18.24	14.90	12.18	22.99	17.27	14.09
	CV (%)	9.17	8.60	6.37	18.05	16.94	18.28	19.93	15.12	17.91

Partial budget analysis

The partial budget analysis of the research showed that applying 92 kg N/ha and 46 kg P_2O_5 ha^{-1} had highest net benefit of 188326.5 ETB ha^{-1} with MRR of 4173.73% and followed by 46 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} with a net benefit of 177361.4 ETB ha^{-1} and MMR of 2506.82% (Table 2).

Table 2. Partial budget analysis result of the research

Fertilizer (kg ha^{-1})		Yield*	Gross benefit*	Cost*	Net benefit*	MRR%
Nitrogen	P_2O_5					
0	0	43.13	134827.2	0	134827.2	
0	23	45.21	135650.7	694.87	134955.8	18.51
46	0	48.76	146291.4	1114.75	145176.7	2434.22
0	46	46.25	138763.8	1389.75	137374.1	D
46	23	53.91	161751.6	1809.62	159942	2124.91
0	69	43.65	130977	2084.65	128892.4	D
92	0	53.56	160706.7	2229.5	158477.2	D
46	46	59.94	179865.9	2504.5	177361.4	2506.82
92	23	54.08	162248.4	2924.37	159324	D
46	69	49.38	148151.7	3199.4	144952.3	D
92	46	63.98	191945.7	3619.25	188326.5	4173.73
92	69	59.45	178372.8	4314.15	174058.7	D

**= Yield is the yield in quintal ha^{-1}, gross benefit is the benefit in ETB ha^{-1} , Cost is the variable cost in ETB ha^{-1-} and net benefit is the net benefit in ETB ha^{-1} while D Stands for dominated treatments*

Conclusion and recommendation

In Ethiopia, low soil fertility is one of the factors limiting the productivity of crops, including garlic. Hence, sustaining soil fertility in intensive cropping systems for higher yields of better quality can be achieved through optimum levels of fertilizer applications. Nitrogen and phosphorus fertilizers are very vital nutrients for growth, development and productivity of crops as well as to improve the productivity of land resource. The result of this study showed a significant response in yield to the applied rates of nitrogen and phosphorus. Growth and yield of garlic increased significantly with increasing rate of nitrogen and phosphorus fertilizer. Thus, application of nitrogen and phosphorus at the rate of 92 kg N and 46 kg P_2O_5 ha^{-1} had 2.21 t ha^{-1} yield advantage over the control (no fertilizer). Application of 92 kg N ha^{-1} and 46 kg $P_2O_5ha^{-1}$ gave the highest economic return followed by 46 kg N ha^{-1} and 46 kg P2O5 ha^{-1}. Therefore, the combination of 92 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} is recommended for Kechin Abeba irrigation scheme and similar agro-ecologies to produce maximum yield garlic yield. Further work on integrated nutrient management for further increase in productivity is crucial.

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Response of green and hot pepper to nitrogen and phosphorus fertilizers at Koga irrigation scheme, in west Amhara, Ethiopia

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Abstract

A field experiment was conducted to determine nitrogen (N) and phosphorus (P) rates for green pepper (*Capsicum frutescens*) yield at Koga irrigation scheme. A randomized complete block design (RCBD) with three replications was used constituting five rates of N (46, 69, 92, 115,138 kg ha^{-1}) and three rates of P_2O_5 (46, 69 and 92 kg ha^{-1}) combined in a factorial arrangement including 0,0 rates of N and P for comparison as a negative check. All TSP (P source) was applied during transplanting while urea (N source) was applied in two splits: half at transplanting and half at the start of flowering. Marekofana pepper variety was used as a test crop. The plots were irrigated by furrow every seven days. All data were collected and analyzed using SAS software and means were separated by Duncan's Multiple Range Test at 5% for significant treatment mean differences. The result showed that there was highly significant difference among treatments and years but the interaction between treatments and years was not significant. The highest marketable green pod yield (15.52 t ha^{-1}) was obtained from 138 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} whereas the lowest marketable yield (11.38 t ha^{-1}) was obtained from 46 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1}. The partial budget analysis for marketable yield also showed that applying 138 kg N ha^{-1} with 69 kg P_2O_5 ha^{-1} had the highest net benefit (64777.2 ETB ha^{-1}) with a MRR 546.05%. Therefore, combined application of 138 kg N ha^{-1} with 69 kg P_2O_5 ha^{-1} or 242 kg urea and 150 kg DAP ha^{-1} is recommended for Koga irrigation scheme.

Key Words: fertilizer, hot pepper, marketable yield, nitrogen, phosphorus,.

Introduction

Hot pepper (*Capsicum frutescens*.) is one of the most important spice and vegetable crops widely cultivated around the glob for its pungent flavor and aroma (Ikeh et al., 2012; Obidiebub et al., 2012). It has been a part of the human diet since about 7500 BC (Mac Neish, 1964 in Sileshi, 2011). Hot pepper belongs to the genus Capsicum and family Solanaceae. In Ethiopia, hot pepper is commonly cultivated within an altitude ranges of 1400 to 1900 meter above sea level (m.a.s.l) and extensively grown at altitude of 1100 to 1800 m.a.s.l. (MoARD, 2009; EIAR, 2007), which receives mean annual rainfall of 600 to 1200 mm, and has mean annual temperature of 25 to 28°C (EIAR, 2007).

Hot pepper is produced both in the rainy and irrigation seasons in Ethiopia. In irrigated agriculture, it is produced mainly for green pod (as vegetable) while in the rainy season for both spice and vegetable. In Ethiopia, hot pepper powder is used as an essential coloring and flavoring ingredient in traditional diets whereas the green pods are usually consumed with other foods.

In terms of total production the share of pepper is high as compared with other vegetables such as lettuce, tomatoes and others (CSA, 2013). In Ethiopia vegetable production accounts about 1.43% of the area under all crops. However, of the total estimated area under vegetables, the lion share which is about 70.89% and 18.07% was under hot peppers and Ethiopian cabbage, respectively (CSA, 2013). Production of vegetables contribute 2.95% of the total crops production, conversely, of the total production of vegetables, hot pepper and head cabbage are the highest which is about 37.14% and 43.53%; respectively (CSA, 2013). In Amhara region 1,508.06 ha of land was allocated for green pepper and 50,585.59 ha of land was allocated for dry pepper production in 2012/13 cropping season (CSA, 2013). The production of hot pepper was 12,017.43 tonnes and 97,901.92 tonnes in the same year for green and dried pod yield; respectively (CSA, 2013).

Pepper is a heavy feeder, needing large amounts of nutrients to produce quality product, mainly just after 10 days of flower initiation to the beginning of fruit ripening (Zhang et.al. 2002). Under intensive production systems, the hot pepper needs fertilizer at transplanting to promote root establishment and shoot development while at flowering to ensure flower set and fruit retention, and during harvesting for continued production (FAO, 2004).

Irrigated area has been increasing from time to time in Ethiopia (Awulachew *et al.*, 2007) that needs research support including for fertilizer package. In Amhara region the newly developed irrigation schemes like Koga needs research based and area specific fertilizer recommendations. Even if, the blanket recommended fertilizer rate for hot pepper in Ethiopia is, 200 kg DAP ha^{-1} and 100 kg urea ha^{-1} (EARO, 2004), there must be area specific fertilizer recommendation.

Therefore, the objective of this research was to determine optimum nitrogen and phosphorous fertilizer rates for Koga irrigation scheme.

Materials and methods

The experiment was carried out at Koga irrigation scheme which is situated in Mecha district of West Gojam Zone, Amhara National Regional State, Ethiopia. The mean annual rainfall at Merawi town is 1589 mm and the mean annual temperature ranges from 16 to 20^{o}C (Nigussie and Yared, 2010).

The dominant soil type in Koga irrigation scheme is Nitisols (Yihenew, 2002) and it is in general moderately acidic in reaction (Yihenew, 2002; Birru *et al*., 2013). However, there are some cases where the soil is strongly acidic with high exchangeable acidity and high exchangeable Al content. It has very low organic matter and low available phosphorus content according to the category set by Clements and McGowen (1994). It also has medium total nitrogen contents (Table 1). The command area of Koga irrigation scheme is 7,000 ha (Figure 1).

Experimental setup

The field experiment was carried out in 2011 and 2013 using 16 treatments including five rates of N (46, 69, 92, 115,138 kg ha^{-1}) and three rates of P_2O_5 (46, 69 and 92 kg ha^{-1}) combined in a factorial arrangement including 0, 0 rates of N and P for comparison as a check in three replications. Triple Super Phosphate (TSP) fertilizer (as a source of phosphorus) was applied at transplanting whereas urea (as a source of N) was applied in two splits half at transplanting and half at flowering. Seedling of “Mareko Fana” variety was raised in a well prepared seed bed for 45 days before transplanting. The spacing of 30 cm between plants and 70 cm between rows was used; respectively in the field. The gross size of each experimental plot was 2.8m by 3m (8.4m^2) and a net harvested plot size of 4.5m^2. Irrigation water was supplied on weekly basis with furrow irrigation system.

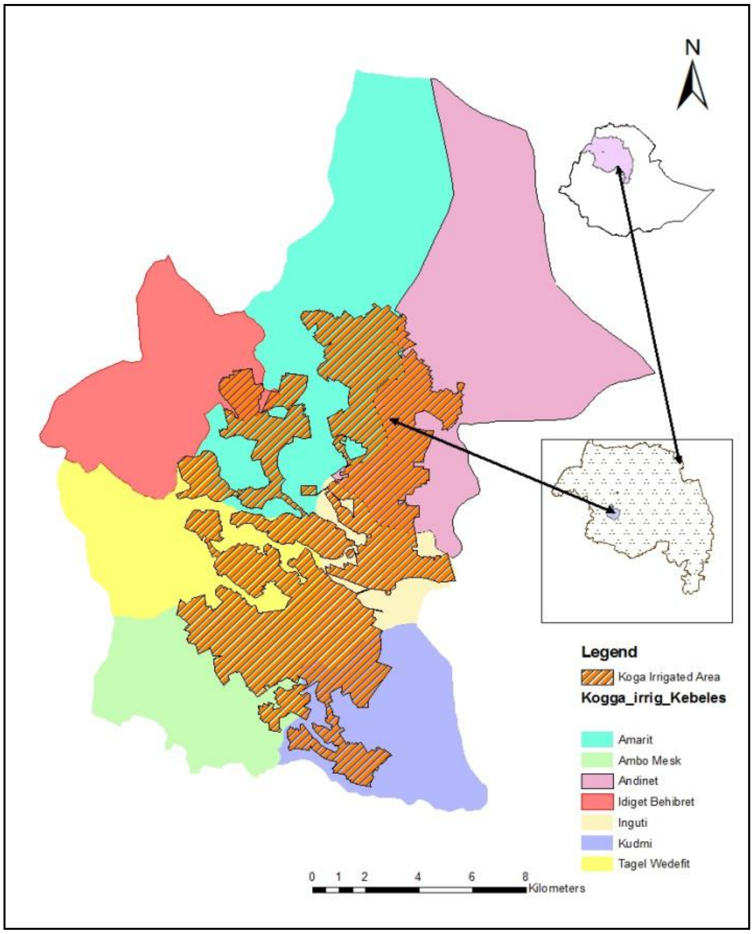

Figure 1. Koga irrigation command area in the Koga watershed (Anteneh *et al*., 2014)

Data on plant height was recorded from five randomly selected plants and fruit length and fruit diameter were recorded in each harvest from ten randomly selected green pods of the net plot. Whereas, maturity, stand count, marketable fruit yield and total fruit yield were recorded from the whole plant in the net plots. (Analysis of variance (ANOVA) for yield and yield components were employed using SAS version, 9.2 (SAS, 2008). In conditions where ANOVA was significant, the treatment means were compared using Duncan's multiple range test (DMRT) at 5% probability. Economic analysis had also been performed following the CIMMYT partial budget methodology (CIMMYT, 1988). The analysis was done in the first case with the normal prices of yield and costs of inputs. Sensitivity analysis was also performed by the assumption that the cost of fertilizer inputs increased by twenty five percent while the cost of the green pod remained constant. The analysis was made based on data collected from Mecha district office of Trade and Transport, Cooperatives and from hot pepper producing farmers' field. At Mecha, the minimum mean price of hot pepper during the study time was 5.00 ETB kg^{-1}, while the price of urea and DAP was 11.88 ETB kg^{-1} and 14.64 ETB kg^{-1}; respectively.

Results and discussions

The soil reaction (pH) of the experimental site on average was 5.2 (Table 1). According to Bruce and Rayment (1982), the soil is considered as strongly acidic and moderately good for crop production through efficient management of soil nutrients. The CEC of the soil was 25.00 cmole kg^{-1}, which is in a range of moderate to high (Bruce and Rayment, 1982). According to the ratings of Bruce and Rayment (1982) the total nitrogen of the area lies in medium range. Actually total nitrogen is an indication of the total amount of nitrogen present, but it does not guarantee for the availability of nitrogen to the plant. The highest proportion of the total nitrogen is held in by the soil organic matter and hence is not immediately available to plants (Hazelton and Murphy, 2007). Total nitrogen cannot be used as a measure of the mineralized forms of nitrogen (NH_4^+, NO_3^-, NO_2^-), as much of it is held in the organic matter. Available phosphorus was low; this could be due to low soil pH and fixation of P by Al and Fe. Soil organic matter of the site was at about the critical level. Soil organic matter plays a great role for structural stability (Charman and Roper, 2007) as well as.it influences physical and chemical properties of soils.

Table 1**.** Chemical properties of the soils of Koga irrigation scheme in 2011

pH*	TN*	Available P*	SOM*	CEC*	Texture (%)			
					Sand	Silt	Clay	Class
5.13	0.21	6.28	3.71	25.62	17.56	25.00	57.44	Clay

** pH is in water, TN is total nitrogen in % , Available P is in ppm, SOM is soil organic matter in % and CEC is cation exchange capacity in centimol per kg of soil*

The ANOVA of marketable yield showed significant difference ($p<0.01$) over years, but year * N * P was not significant (Table 2).

Table 2. Combined ANOVA for the effect of N and P fertilizers on marketable and total yield of hot pepper at Koga irrigation scheme

Source of variation	DF	Mean Square Value			
		Marketable pod yield	Pr > F	Total pod yield	Pr > F
Rep	2	1.5825478	0.6428	2.4438478	0.5530
N	4	18.3719844	0.0012	24.1949794	0.0005
P	2	5.5737344	0.2171	5.6889544	0.2564
Year	1	211.906777	<.0001	138.8556011	<.0001
N*P	8	2.5374303	0.6782	2.0689544	0.8464
Year*P	2	8.3444344	0.1046	7.6760211	0.1618
Year*N	4	5.2232556	0.2232	5.2399817	0.2871
Year*N*P	8	1.6731164	0.8718	1.9283683	0.8707

Except for the plant height, the interaction of N and P didn't show a significant difference ($p>0.05$) for all yield parameters (Table 3). The highest plant height (58 cm) was obtained from the maximum N and P rates (138 N and 92 P_2O_5 kg ha^{-1}) whereas, the lowest plant height (46.23 cm) was obtained by applying 46 N and 69 P_2O_5 kg ha^{-1} (Figure 3). This is agreed with the findings of El-Tohamy et al. (2006) and Abebayehu Aticho et al. (2014) who reported that adequate amount of nutrient supply improved the growth, height, branch and pods of hot pepper.

Table 3. Three ways ANOVA on yield components of hot pepper

Source	Variables	DF	Squares	Mean square	F Value	Pr >
N*P	Plant height	8	477.696898	59.712112	2.94	0.0079
N*P	Fruit diameter	8	0.1389489	0.0173686	0.51	0.8437
N*P	Fruit length	8	4.93460444	0.61682556	0.84	0.5744
N*P	No of fruits/plant	8	269.958524	33.7448156	1.44	0.2005

Even though, number of fruits didn't show significant difference ($p>0.05$) the highest rates (92/46; 138/92 and 138/69 N/P_2O_5 kg ha^{-1}) gave the highest number of fruits (24.83, 24.74 and 24.29; respectively) as compared to lower rates. As nitrogen and phosphorus rates increased, plants can access nutrients easily and can develop new flower buds as a consequence number of fruits increased. Positive response of fruit number for fertilizer was also reported by Amare *et al.* (2013) who recorded highest number of fruits (25.53) per plant by applying 60 kg ha^{-1} and Adugna (2008) also reported that high level of nitrogen and phosphorus fertilizers (150 kg N ha^{-1} with 50 kg P_2O_5 ha^{-1}) gave the highest number of pods per plant compared to the yield obtained from the control.

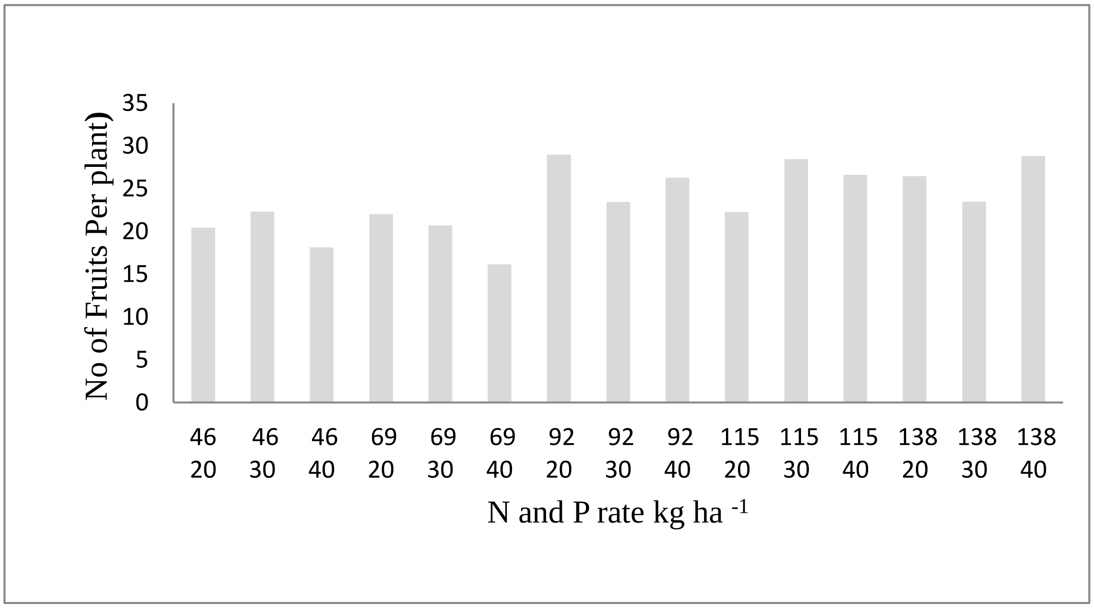

Figure 2. Effect of Nitrogen and Phosphorus Fertilizers on number of fruits per plant

Although there was a non significant difference ($p > 0.05$) between and among treatments on marketable yield, there was a 4.12 t ha^{-1} yield advantage in green pod by applying 138 kg N ha^{-1}

and 92 kg P_2O_5 ha^{-1} than applying 46 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} (Figure 2). Relatively high yield (15.52 t ha^{-1}) was obtained from plots receiving 138 kg N and 69 kg P_2O_5 ha^{-1}, whereas relatively low yield (11.18 t ha^{-1}) was obtained from plots receiving 46 kg N and 46 kg P_2O_5 ha^{-1}, (Figure 3). As nitrogen and phosphorus rates increased, marketable fruit yield was also relatively increased (Figure 3). This may be attributed to good plant performance by nitrogen and phosphorus fertilizer application. Marketable pod yield increment due to application of fertilizer in poor or degraded soil may be due to an increase of vegetative growth and better leaf area that improves the photosynthetic capacity and that leads to better assimilation and production of pods (Matta and Cotter, 1994). Similar was obtained by Amare et al., (2013). They obtained the highest marketable dry pod yield (1.91 t ha^{-1}) from plots received 92 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1}.

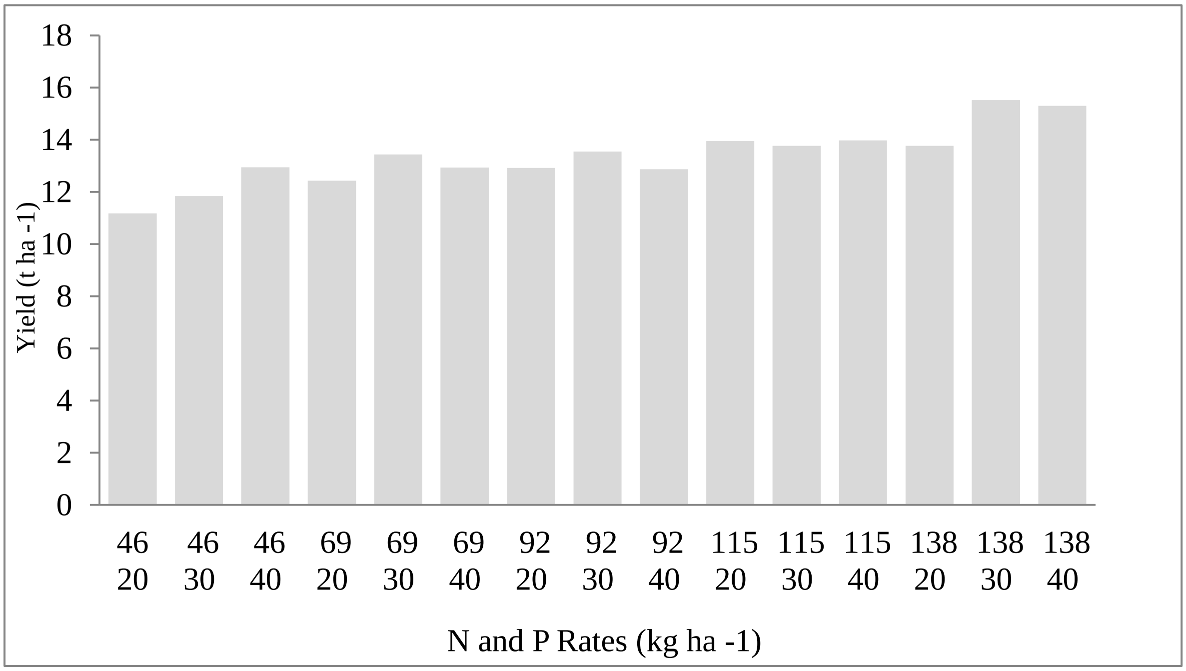

Figure 3. Effect of N and P rates rate on marketable green pod yield

Nitrogen rate independently showed a significant difference ($p<0.01$) on marketable yield (Table 2). The highest marketable yield (14.87 and 13.90 t ha^{-1}) was obtained from plots received 138 and 115 kg N ha^{-1}; respectively. It had a yield advantage of 22.08% and 14.12 % over the plots which received 46 kg N ha^{-1} (Figure 4). This could be due to nitrogen nutrient contribution for vegetative growth such as branches, leaves and height is higher. This is in line with the findings of El-Tohamy et al., (2006) who found adequate amount of nutrient supply improves the growth of hot pepper height, branch and pods.

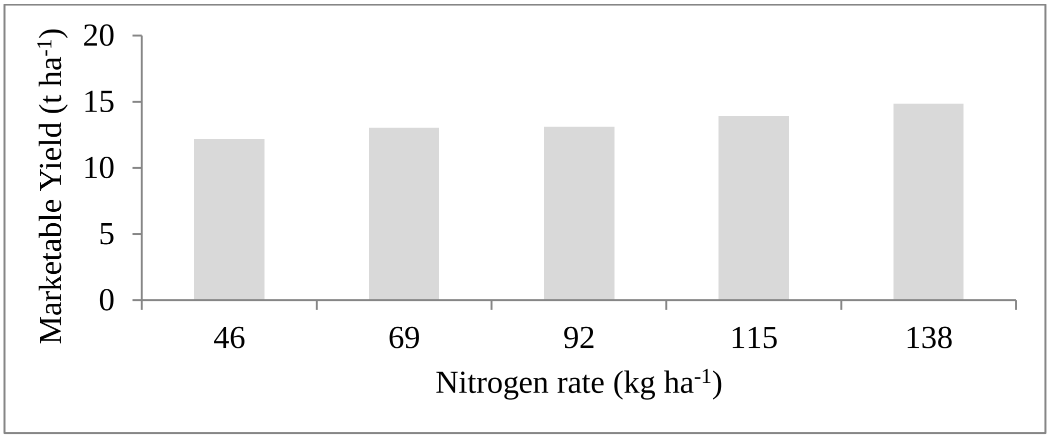

Figure 4. Contribution of nitrogen fertilizer on marketable pod yield of hot pepper

Table 3. Economic and sensitivity economic analysis for hot pepper green pod yield at Koga

	Normal Economic analysis				Sensitivity Economic analysis			
N-P_2O_5 (kg ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)	Rank	TVC ETB ha^{-1}	NB ETB ha^{-1}	MRR (%)	Rank
0-0	0.00	32827.5			0	32827.5		
46-46	2187.13	48122.87	699.3		2187.13	47663.6	560.6	
46-69	2686.70	50593.3	494.5		2686.7	50029.1	391.3	
69-46	2781.13	53153.87	2711.46		2781.13	52569.8	2223.5	
46-92	3186.26	55043.74	466.5		3186.26	54374.6	368.2	
69-69	3280.70	57154.3	2235.0		3280.7	56465.4	1829.7	
92-46	3375.13	54764.87	D		3375.13	54056.1	D	
69-92	3780.26	54404.74	D		3780.26	53610.9	D	
92-30	3874.70	57100.3	D		3874.7	56286.6	D	
115-46	3969.13	58805.87	239.9	2nd	3969.13	57972.4	180.9	2nd
92-92	4374.26	53540.74	D		4374.26	52622.1	D	
115-69	4468.70	57496.3	D		4468.7	56557.9	D	
138-46	4563.13	57401.87	D		4563.13	56443.6	D	
115-92	4968.26	57896.74	D		4968.26	56853.4	D	
138-69	5062.70	64777.3	546.1	1st	5062.7	63714.1	433.9	1st
138-92	5562.26	63287.74	D		5562.26	62119.7	D	

Where: TVC = Total Variable cost in Birr/ha, NB = Net benefit in Birr/ha, MRR = Marginal Rate of Return.

Although the biological yield of hot pepper was promising, the economic and profitable marketable yield should be recommended for farmers producing green hot pepper for the market.

According to CIMMYT (1988) the highest net benefit 64777.3 and 63511.63 ETB per hectare was obtained by applying 138 kg N and 69 kg P_2O_5 ha^{-1} on both dominance and sensitivity analysis; respectively. The highest rate for this particular experiment 138 kg N and 92 kg P_2O_5 ha^{-1} was dominated by 138 kg N and 69 kg P_2O_5 ha^{-1} (Table 3).

Conclusion and recommendation

Based on biological and partial budget analysis of the research applying 138 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} or 246 kg urea ha^{-1} and 150 kg DAP ha^{-1} gave the mean maximum marketable green hot pepper yield (15.52 t ha^{-1}). This is economical optimum and hence recommended for Koga irrigation scheme. Other soil factors like soil acidity may influence to realize achievable yield. Therefore, further research work on integrated soil fertility management including soil acidity management is critically important at Koga irrigation scheme.

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Performance of hybrid maize (Zea mays L.) varieties at Kobo irrigation site, North Wollo, Amhara Region.

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Abstracts

A field experiment was conducted at Kobo sub center in Raya kobo district North Wollo zone of the Amhara Region during 2013 and 2015 cropping seasons to select high yielder and most adaptable maize variety/varieties. The trial was laid out in a randomized complete block design (RCBD) with three replications. A total of seven maize varieties were planted including the local check. DAP (100 kg ha^{-1}) was applied at planting while urea (50 kg ha^{-1}) was applied in two splits at planting and knee height. The plots were irrigated by furrow irrigation every 14 days. All data were collected following standard procedures and were analyzed using Genstat program version 14 and significant treatment mean were separated using least significant difference at 5%. The analysis of variance revealed the presence of significant difference ($P<0.001$) for days to flowering, number of ears harvested and grain yield. The mean grain yield was 4265 kg ha^{-1} ranging from 5586 kg ha^{-1} (BHQPY-545) to 3363 kg ha^{-1} (local). The hybrids BHQPY-545 and BH-661 gave the highest grain yield. Therefore; BHQPY-545 and BH-661 are recommended for Kobo irrigation scheme and similar environments.

Key words: Amhara, grain yield. irrigation, maize, Raya Kobo

Introduction

Maize (Zea mays L.) belongs to a tribe maydea of the family poacea (Graminea). It is believed that the crop was originated in Mexico and introduced to West Africa in the early 1500s by Portuguese traders (Dows well et al., 1996; McCann, 2005). According to some reports, maize was introduced to Ethiopia in 1600s to 1700s (Haffanagel, 1961). Maize stands first in production and yield among main cereals in Ethiopia and second in Amhara region (CSA, 2013). Maize has a wider range of uses as compared to any other cereal crops in the world (Singh, 2007). It is used as a human food, feed for livestock and industrial purposes (Dowswell et al., 1996). Millions of people depend on maize for their daily food in Sub-Saharan Africa (Pixley and Bjarnason, 2002).

In Ethiopia, it is used as a staple food and one of the main sources of calorie in the major maize producing regions, mainly in western, central, southern and eastern regions of the country (MARD, 2007). Maize is cultivated in the major agro-ecological zones of Ethiopia up to altitudes of 2400 m.a.s.l. It grows from moisture stress areas to high rainfall areas and from lowlands to highlands (Kebede et al., 1993). There are wider ranges of potential agro-ecologies for maize production in Ethiopia. However, maize yield levels have remained stagnant due to different challenging biotic and abiotic stresses resulting in unavailability of improved maize technologies in these agro-ecologies (Mosisa et al., 2001b). Such greater variation in environment can severely hinder the development and performance of maize cultivars suitable for extended areas of land.

Maize breeding in Ethiopia started about half a century ago and passed through distinct stages of research and development (Kebede et al., 1993). In the late 1960s and early 1970s, different promising hybrids and composite varieties of East African origin were introduced and evaluated at different locations. However, most of these varieties have been replaced by locally developed and better adapted varieties (Mossisa et al., 1994). Due to unlimited effort of national agricultural research centers and other private seed enterprises like pioneer, until now more than forty improved maize varieties were released in order to tackle the existing maize production constraints of the country. But these released varieties did not bring the expected yield increment, particularly in Amhara region where less numbers of representative sites were used, during these varieties development (Melkamu et al., 2014). Even though the crop is important in north Wollo, its productivity has been constrained by a number of factors. Lack of improved varieties, less adoption of released varieties, poor utilization of inputs (fertilizers), improper crop management and less affordability of quality hybrid seed in the required amount are the major maize production constraints (Melkamu et al.,2014). In the Kobo Girana valley, recommending high yielder maize variety or varieties is critically important since this crop covers more irrigated area than any other cereal crops grown in rotation with irrigated vegetables in the region (Yenesew et al, 2009). As a result this experiment was conducted to identify well adapted and high yielding maize variety for Kobo Girana irrigation scheme.

Materials and methods

A total of seven improved varieties were planted together with local check at Kobo under irrigation. The site is located at about 50 kilometers from Woldiya town to the north-east direction and situated at 12.080 N latitude, at 39.280 E longitudes and at an altitude of 1470 m a s l. The 15 years mean annual rainfall of the location is about 630 mm, but the rainfall during the crop growing period (at time of irrigation) was 262mm. i.e. beyond normal furrow irrigation (65mm month^{-1}) on average taking 4 month is sufficient for maturity. The soil for the experimental site is a silty clay loam type. The experiment was laid in a randomized complete block design (RCBD) with three replications. Spacing between row and between plants was 75 cm and 25 cm; respectively. The plot size was 4m by 3 meters. The amount of fertilizer used was 100 kg DAP and 50 kg urea ha^{-1}; respectively. Nitrogen was splited in to two (half at planting and half knee height stage) while DAP was applied once at planting. Data was collected for days to female flowering/silking, days to male flowering/tasseling, plant height (cm), number of harvested plants per plot, number of harvested ears per plot, ear aspect, days to maturity, biomass weight (kg ha^{-1}) and grain yield (kg ha^{-1}). Statistical data analysis was done using Genstat program version 14. Variance ratio test for homogeneity of variance was carried out to determine the validity of the individual experiment while treatment mean separation was done using least significance difference (LSD) at 5% level of significance.

Results and discussions

The result showed that a significant variation ($P<0.001$) among and between varieties for days to anthesis, days to silking, number of ear, ear aspect, days to maturity, biomass (green cob) and grain yield (Table 1). The local variety and MH-130 took fewer days to anthesis/tasseling and siliking i.e 65 and 68 days; respectively (Table 1). Most of the tested hybrid varieties took longer days to flowering. These late maturing hybrid were released for areas with sufficient rainfall. The same result was reported by Jemal et al., (2015) stated hybrids released for moisture stress ecologies took lesser mean days to flower than hybrids developed for high potentials. The numbers of ears were lower for BH-140 followed by BH-540 (Table3). The best ear aspect was recorded for BH-661and BHQPY-545, respectively (Table 1). Poor performance in ear aspect was observed for the local variety (Table 2). The number of ears was higher for local variety but with low grain yield compared to other varieties (3363 kg ha^{-1}). This showed that grain filling, number of row per cob and number of kernel per row is more important than number of ears (Table 3).

Table 1.The mean performance of maize varieties evaluated for grain yield and yield related traits in 2013.

Varieties	DT	DS	Ph	SC	CN	MD	CW	GY	EA
MH-130	59	63	182	64.0	64	118	7833	5151	2
MHQ-138	68	70	194.3	64.0	63	128	5667	4130	3
BH-140	70	74	201.7	64.0	49	134	4723	4207	3
BH-540	69	71	210.7	64.0	59	138	7444	4902	2
BHQPY-545	67	69	199.7	61.7	66	132	8278	6131	1
BH-660	76	79	218	58.7	58	150	4333	3609	3
BH-661	74	77	237.3	64.0	67	150	6833	5177	1
Local(Emawaysh)	59	62	214	64.0	69	119	6111	3627	4
CV (%)	1.6	1.4	4.5	3.7	9	4.5	9	10.5	1.2
LSD (5%)	1.9	1.8	16.27	ns	9	11	1208	837	1.2

DT= days to tasseling, DS= days to silking, ph=plant height, SC=stand count (per 12m^2) CN=cob number (per 12m^2), CW= cob weight (kg ha^{-1})*, MD=days to maturity, GY=grain yield* (kg ha^{-1})*, EA=ear aspect.*

The least grain yield was also recorded in the year 2015 from the local variety (Table 2). In the same year BHQPY-545 (5041 kg ha^{-1}) recorded the highest field weight (cob weight) followed by BH-661(4652 kg ha^{-1}) (Table 2). Similarly, the highest mean grain yield and cob weight combined over years was recorded by BHQPY-545 followed by BH-661 (Table 3). Consistently BHQPY-545 gave the highest grain yield and cob weight followed by bH-661 (but dominated by MH-130 only for cob weight during 2013) while the lowest was from the local variety (Table 3). This result is in agreement with Melkamu et al., (2014) in which farmers around western Amhara selected this variety for its' earliness. The main reason for poor protein quality of normal maize is the relatively high concentration of prolamines (zeins) storage proteins (50-60%) which are devoid of lysine and tryptophan (Mertz, 1992). This study revealed that BHQPY-545 performed well in the tested site and was one of best hybrids that perform well in Ethiopia Jemal. et al (2015).

Table 2. The mean performance of maize varieties evaluated for grain yield and yield related traits in 2015.

Varieties	DT	DS	Ph	SC	CN	MD	CW	GY	EA
MH-130	72.0	74.7	147.0	55.7	49.7	120	7056	3661	2

MHQ-138	80.7	81.7	179.7	53.7	59.7	130	9333	3964	3.5
BH-140	82.7	84.0	183.3	49.3	46.0	136	8389	3285	3.5
BH-540	83.7	84.7	136.7	49.3	44.0	140	8223	3769	3
BHQPY-545	82.7	84.0	186.3	57.0	62.7	133	10723	5041	2
BH-660	85.7	87.3	230.7	50.7	51.3	148	10139	3840	2.5
BH-661	83.0	84.7	219.0	61.7	61.7	148	10778	4652	2
Local	71.7	74.3	194.0	55.0	61.7	119	6389	3099	4.5
Mean	80.3	81.9	184.6	54.1	54.6	134	8878	3914	2.8
CV	2.2	2.3	20.4	10.7	14.3	5.2	14.6	13.3	2
LSD(5%)	3.0	3.2	65.0	10.1	13.6	12.	2715	912	1.5

DT= days to tasseling, DS= days to silking, ph=plant height, SC=stand count (per 12m^2) CN=cob number (per 12m^2), CW= cob weight (kg ha^{-1}), MD=days to maturity, GY=grain yield (kg ha^{-1}), EA=ear aspect.

Table 3.The combined mean performance of maize varieties evaluated for grain yield and yield related traits in 2013 &2015.

Varieties	DT	DS	Ph	SC	CN	MD	CW	GY
MH-130	65.7	68.7	164.5	59.8	56.7	119	7833	4406
MHQ-138	74.3	76.0	187.0	58.8	61.3	129	5667	4047
BH-140	76.3	79.0	192.5	56.7	47.7	135	4723	3746
BH-540	76.2	77.8	173.7	56.7	51.5	139	7444	4336
BHQPY-545	74.8	76.7	193.0	59.3	64.2	132.5	8278	5586
BH-660	80.8	83.2	224.3	54.7	54.5	149	4333	3725
BH-661	78.3	80.8	228.2	62.8	64.3	149	6833	4915
Local	65.3	68.3	204.0	59.7	65.7	119	6111	3363
CV (%)	4.8	8.6	15.6	11.8	13.0	4.8	13.7	10.3
LSD (5%)	8.4	7.6	35.7	8.0	8.8	11.2	1130	515

DT= days to tasseling, DS= days to silking, ph=plant height (cm), SC=stand count (per 12m^2) CN=cob number (per 12m^2), CW= cob weight (kg ha^{-1}), MD=days to maturity, GY=grain yield (kg ha^{-1}), EA=ear aspect.

Conclusion and recommendation

Maize varieties showed significant variation ($P<0.001$) for days to tasseling, days to silking, cob number, ear aspect, days to maturity and grain yield. BHQPY-545 and BH-661 gave the highest mean grain yield 5586 kg ha^{-1} and 4915 kg ha^{-1}; respectively. Therefore, BHQPY-545 and BH-661 maize varieties are recommended for Kobo under irrigation under irrigation for grain yield.

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Performance of improved tomato (*Lycopersicum esculentum* Mill.*)* varieties in the lowlands of Aberegelle, Waghimra Zone.

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Abstract

Twelve nationally released varieties of tomato were evaluated in randomized complete block design with three replications during 2013 and 2014 at the low lands of Aberegelle, Waghimra Zone, under irrigation. The objective of the experiment was to select adaptable and high yielding tomato varieties. All plots were irrigated by furrow every three days and 100 kg DAP was applied at transplanting and 100 kg urea was applied in two splits (half at transplanting and the other half at 45 days after transplanting). The collected data were analyzed using SAS statistical software and means were separated using least significant difference at 5% for significant treatment mean differences. The combined analysis of variance over year showed that there was significant difference among years and varieties (at $p<0.01$) for all observed characters. Similarly, significant difference between varieties by year interaction for number of cluster per plant, average fruit weight (gm) and number of unmarketable fruits was also observed. A positive correlation existed between total yield and number of cluster per plant ($r=0.46$), number of fruit per cluster ($r=0.49$), number of marketable fruits ($r=0.77$), marketable fruit yield ($r=0.98$), and total number of fruits ($r=0.74$). The varieties Melkasalsa (12607.40 kg ha^{-1}) followed by Cochero (12169.60 kg ha^{-1}) gave the highest total fruit yield combined over seasons. Therefore, Melkasalsa and Cochero varieties are recommended for Aberegelle and similar environments under irrigation.

Key words: correlation, fruit yield, irrigation, tomato, Waghimra.

Introduction

Tomato *(Lycopersicum esculentum* Mill.) is an annual herb which belongs to the family solanaceae and grown for its fleshy berry fruit. It is one of the most important edible and nutritious horticultural crops in the world and widely cultivated in tropical, sub-tropical and temperate climates. Tomato is one of the most important horticultural crops grown in Ethiopia.

Mainly, two types of tomato are produced in the country; the fresh market types which are used for local market and the processing types mainly bred for processing (Tibebu and Aleminew, 2008).

The climatic soil conditions of Ethiopia allow cultivation of a wide range of fruit and vegetable crops including tomato, which is largely grown in the eastern and central parts of the mid- to low-land areas of the country (Meseret *et al*., 2012). In 2013, tomato production in Ethiopia reached about 55,514.28 tonnes from a total harvested area of 7,237.35 ha with average productivity of 7.67t ha^{-1}(CSA, 2013).

Even though Waghimra zone is a dry land area which receives low and erratic rain fall, the lowland part of the zone in particular is endowed with favorable environmental conditions for the production of cash crops under irrigation. However, the production of tomato is low, and hardly meets the local market due to lack of improved varieties. Improving the productivity of tomato by introducing released and high yielding fresh market tomato varieties will have a contribution to enhance income of farmers in the area. In the year of 2005/2006 dry seasons Sekota Dryland Agricultural Research Center evaluated the performance of tomato varieties in the mid lands of the Waghimra (Tibebu and Aleminew , 2008). Therefore, this study was conducted to evaluate and recommend well adaptable and high yielding tomato varieties for the low lands of Aberegelle areas of Waghimra Zone.

Materials and method

The experiment was conducted on farmers` field at Aberegelle district. The geographical location of the study area lies $38^o$ 56`to 39^o 25 East and 12^o 14`to $13^o$ 10` North with an elevation about 1350 m.a.s.l. The soil study site is characterized with sandy loam soil. It was executed during 2013 and 2014 dry seasons under irrigation conditions. Seedlings were raised in nursery where the beds were thoroughly prepared. Twelve improved tomato varieties were collected from Melkassa and Sirinka agricultural research centers and used for the study. The experimental plots were laid in a randomized complete block design (RCBD) with three replications. The plot size was 5m by 3m dimensions to accommodate 50 plants per plot with spaces of 0.3 m and 1m between plants and between rows; respectively. The spacing between plots and blocks was 0.5 m and 1 m; respectively. Watering after transplanting was made using furrow irrigation at three days irrigation interval following farmers' practice in the study area.

The rate of 100 kg ha^{-1} and 100 kg of DAP ha^{-1} was used. Urea was applied by splitting: half at planting and half 45 days after transplanting while the whole DAP applied at transplanting.

Data were recorded for days to flowering, days to maturity, number of fruits per cluster, number of clusters per plant, average fruit weight number and weight of marketable fruits, number and weight of unmarketable fruits, number and weight of total fruit yield and farmers` opinion towards the varieties. In this experiment; fruits with cracks, damaged by insect, disease or bird undersized and those with sun burn were considered as unmarketable fruits. Collected data were subjected to statistical analysis using SAS software (version 9.0) and mean differences were tested for their significance difference using least significant difference test (LSD). Pearson`s correlation was computed to evaluate the relationship between collected data of yield and yield components.

Results and discussions

The analysis of variance for the 2013 cropping season revealed a highly significance difference among the tomato varieties (at $p<0.01$) for all characters except unmarketable fruit yield (Table 1). Variety Melkasalsa gave the highest total fruit yield (13.05 t ha^{-1}) followed by Miya (12.6 t ha^{-1}) and Woyno (12.6 t ha^{-1}). In 2014, Cochoro (12.5 t ha^{-1}) gave the highest total fruit yield followed by Melkasalsa (12.2 t ha^{-1}) and Woyno (11.1 t ha^{-1}) (Table 2).

The combined analysis of variance over years showed that there was statistically significant difference among years and varieties (at $p<0.01$) for all the observed characters (Table 3). Statistically significant difference between varieties by year interaction for number of cluster per plant, average fruit weight (gm.) and number of un-marketable fruits was observed (Table 3). This implies that the varieties had inconsistent performance for these parameters over seasons. A non-significant difference was observed for other characters which imply that there is consistent performance of the varieties for these characters over seasons (Table 2). Melkasalsa gave the highest total yield (12.6 t ha^{-1}) followed by Cochoro (12.2 t ha^{-1}) combined over seasons (Table 3). Similarly, among the tested varieties, Melkasalsa gave the highest marketable fruit yield (9.3 t ha^{-1}) followed by Cochoro (8.6 t ha^{-1}) (Table 3). The lowest unmarketable yield was recorded from Metadel (2.5 t ha^{-1}) and Eshet (2.6 t ha^{-1}) (Table 3). Although these varieties gave the lowest unmarketable quality fruit, the number and yield of marketable fruits were also very low as compared to other varieties. Positive correlations were observed between total yield and:

number of cluster per plant (r=0.46), number of fruit per cluster (r=0.49), number of marketable fruits (r=0.77), marketable fruit yield (r=0.98), number of unmarketable fruits (r=0.53), unmarketable fruit yield (r=0.83) and total number of fruits (r=0.74) (Table 4). This implies that varieties with higher number of cluster per plant and higher number of fruits per cluster gave superior yield.

The yield of all tested tomato varieties in this area was lower than the yield of the same varieties in the areas where they have been released (Melkasalsa 45.0 t ha^{-1} and Cochoro 46.3 t ha^{-1}) (Minstry of Agriculture and Rural Development, 2007). Tibebu and Aleminew (2008) also reported that Melkasalsa gave a better marketable yield (16.82 t ha^{-1}) in the mid altitude of Waghimera zone. Cochoro variety has been preferred by the farmers for its good firmness, desirable shape (Oblong) and size to the local market. Farmers also liked Melkasalasa for its good number of fruit settings.

Table 1.Yield and yield components for the tested varieties in 2013

Varieties	DF	DM	PH	NCP	NFP	AFW	MN	MY	UMN	UMY	TN	TY
Roma vf	48.8	83.3	43.9	6.7	2.5	31.5	272720	8.5	114517	3.6	387237	12.1
Marglobe	50.7	92.3	78.7	3.5	2.2	37.1	154748	5.8	85906	3.2	240655	9.0
Melkaselsa	41.0	71.0	36.3	9.2	3.3	21.3	434316	9.6	185633	3.9	619949	13.5
Woyno	44.0	76.0	61.9	3.7	2.8	32.7	264892	8.7	118575	3.9	383467	12.6
Mersa	46.7	84.7	71.7	7.3	2.4	33.8	248775	8.3	109655	3.7	358430	12.0
Metadel	49.0	81.0	47.9	2.5	1.3	58.0	76749	4.5	46222	2.7	122970	7.2
Chali	40.0	71.3	35.8	2.4	2.1	28.7	287016	8.2	121660	3.5	408676	11.7
Miya	42.7	73.0	42.8	3.4	2.9	34.5	260031	8.9	106568	3.7	366599	12.6
Eshet	45.0	76.7	80.1	2.1	1.9	51.0	109554	5.2	58694	2.8	168248	8.0
Fetan	48.0	86.0	44.1	2.3	2.5	48.2	150006	7.3	73646	3.5	223652	10.8
Melkashola	51.3	83.7	56.3	2.2	2.2	33.0	217419	7.1	93714	3.5	311133	10.6
Chochoro	43.0	74.7	38.3	3.1	3.4	42.1	200314	8.3	85815	3.6	286129	11.8
CV (%)	6.6	4.7	14.8	21.0	13.2	14.9	21.5	15.6	15.3	12.9	18.7	14.6
LSD (0.01)	5.1	6.4	13.3	1.4	0.6	9.5	81016	2.0	25889	NS	102153	2.7

Where, DF=Days to flowering, DM=Days to maturity, PH= Plant eight (cm), NCP=Number of cluster per plant, NFP= Number of fruit per cluster, AFW= Average fruit weight (gm), MN= Number of marketable fruits, MY = Marketable fruit yield (t ha^{-1}*), UMN= number of unmarketable fruits, UMY= Unmarketable fruit yield ((t* ha^{-1}*), TN=Total number of fruits, TY= Total fruit yield (t* ha^{-1}*).*

Table 2.Yield and yield components for the tested varieties in 2014

Varieties	DF	DM	PH	NCP	NFP	AFW	MN	MY	UMN	UMY	TN	TY
Roma vf	52.0	85.0	50.9	5.0	2.9	49.6	218000	7.4	121111	3.6	339111	11.0
Marglobe	48.3	87.7	66.1	3.1	2.7	38.3	164444	5.1	191778	3.4	356222	8.5
Melkaselsa	43.7	77.0	40.6	7.6	3.5	26.6	426444	8.9	148222	3.3	574667	12.2
Woyno	43.7	77.3	58.8	3.1	3.2	41.3	208222	7.4	127111	3.7	335333	11.1
Mersa	46.3	83.0	71.2	5.2	2.5	36.6	220444	7.1	100667	2.8	321111	9.9
Metadel	51.0	80.3	54.7	2.2	1.7	58.9	85556	4.7	48000	2.2	133556	6.9
Chali	44.7	74.0	34.2	2.4	2.1	33.4	216444	6.8	122000	3.3	338444	10.1
Miya	46.0	77.7	42.5	2.8	3.4	35.1	206444	6.7	122889	3.9	329333	10.6
Eshet	43.7	75.7	73.6	2.5	2.1	48.8	80889	3.8	49556	2.3	130444	6.1
Fetan	47.7	83.3	46.3	2.1	3.1	59.6	110000	5.8	65556	2.9	175556	8.7
Melkashola	52.7	85.0	58.2	2.3	3.1	33.4	185111	5.5	107111	3.1	292222	8.5
Chochoro	43.0	76.0	37.8	2.5	4.1	42.3	196667	8.8	77111	3.6	273778	12.5
CV (%)	6.3	4.2	10.4	12.4	11.5	10.2	16.7	18.4	18.3	18.6	14.04	16.8
LSD (0.01)	5.0	5.7	9.3	0.7	0.6	7.3	54556	2.0	33132	1.0	71340	2.8

Where, DF=Days to flowering, DM=Days to maturity, PH= Plant eight (cm), NCP=Number of cluster per plant, NFP= Number of fruit per cluster, AFW= Average fruit weight (gm), MN= Number of marketable fruits, MY = Marketable fruit yield (t ha^{-1}*), UMN= number of unmarketable fruits, UMY= Unmarketable fruit yield ((t* ha^{-1}*), TN=Total number of fruits, TY= Total fruit yield (t* ha^{-1}*).*

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Table 3.Yield and yield components for the tested varieties combined over years (2013 and 2014)

Varieties	DF	DM	PH	NCP	NFP	AFW	MN	MY	UMN	UMY	TN	TY
Roma vf	50.3	84.2	47.4	5.8	2.7	40.6	245360	8.0	117814	3.6	363174	11.6
Marglobe	49.5	90.0	72.3	3.3	2.4	37.7	159596	5.4	138842	3.3	298439	8.7
Melkaselsa	42.3	74.0	38.5	8.4	3.4	23.9	430380	9.3	166928	3.6	597308	12.9
Woyno	43.8	76.7	60.3	3.4	3.0	37.0	236557	8.0	122843	3.8	359400	11.8
Mersa	46.5	83.8	71.5	6.3	2.5	35.2	234610	7.7	105161	3.2	339771	10.9
Metadel	50.0	80.7	51.3	2.4	1.5	58.4	81152	4.6	47111	2.5	128263	7.1
Chali	42.3	72.7	35.0	2.4	2.1	31.0	251730	7.5	121830	3.4	373560	10.9
Miya	44.3	75.3	42.7	3.1	3.2	34.8	233238	7.8	114728	3.8	347966	11.6
Eshet	44.3	76.2	76.9	2.3	2.0	49.9	95221	4.5	54125	2.6	149346	7.1
Fetan	47.8	84.7	45.2	2.2	2.8	53.9	130003	6.5	69601	3.2	199604	9.8
Melkashola	52.0	84.3	57.3	2.2	2.7	33.2	201265	6.3	100412	3.3	301678	9.6
Chochoro	43.0	75.3	38.1	2.8	3.7	42.2	198490	8.6	81463	3.6	279953	12.2
CV (%)	6.6	4.5	12.5	17.7	12.2	12.4	19.4	16.6	17.1	15.6	16.6	15.3
LSD (0.01)	3.5	4.1	7.7	0.8	0.4	5.7	2.01	1.4	2.1	0.6	60125	1.8

Where, DF=Days to flowering, DM=Days to maturity, PH= Plant eight (cm), NCP=Number of cluster per plant, NFP= Number of fruit per cluster, AFW= Average fruit weight (gm), MN= Number of marketable fruits, MY = Marketable fruit yield (t ha^{-1}*), UMN= number of unmarketable fruits, UMY= Unmarketable fruit yield ((t ha*$^{-1}$*), TN=Total number of fruits, TY= Total fruit yield (t ha*$^{-1}$*).*

Table 4. Pearson`s correlation (r) between yield and yield components

	DF	DM	PH	NCP	NFP	AFW	MN	MY	UMN	UMY	TN	TY
DF	-											
DM	0.79^{**}	-										
PH	0.23^{*}	0.37^{**}	-									
NCPP	-0.15	-0.07	-0.07	-								
NFPC	-0.26	-0.19	-0.35^{**}	0.27^{*}	-							
AFW	0.18	0.16	0.21	-0.49^{***}	-0.34^{**}	-						
MN	-0.37^{**}	-0.34^{**}	-0.36^{**}	0.73^{***}	0.46^{***}	-0.78^{**}	-					
MY	-0.42^{**}	-0.36^{**}	-0.39^{**}	0.51^{**}	0.47^{**}	-0.51^{**}	0.81^{**}	-				
UMN	-0.17	-0.11	-0.19	0.52^{**}	0.39^{**}	-0.67^{**}	0.72^{**}	0.48^{**}	-			
UMY	-0.22	-0.18	-0.22	0.27^{*}	0.40^{**}	-0.39^{**}	0.52^{**}	0.72^{**}	0.61^{**}	-		
TN	-0.33^{**}	-0.29^{**}	-0.33^{**}	0.71^{**}	0.47^{**}	-0.79^{**}	0.97^{**}	0.75^{**}	0.85^{**}	0.59^{**}	-	
TY	-0.38^{**}	-0.32^{**}	-0.36^{**}	0.46^{**}	0.49^{**}	-0.49^{**}	0.77^{**}	0.98^{**}	0.53^{**}	0.83^{**}	0.74^{**}	-

*Where, DF=Days to flowering, DM=Days to maturity, PH= Plant eight (cm), NCP=Number of cluster per plant, NFC= Number of fruit per cluster, AFW= Average fruit weight (gm), MN= Number of marketable fruits, MY = Marketable fruit yield (t ha^{-1}), , UMN= number of Un-marketable fruits, UMY= Unmarketable fruit yield (t ha^{-1}), , TN=Total number of fruits, TY= Total fruit yield (t ha^{-1}), **, *Significant at 1% and 5% respectively; NS= Non- significant*.

Conclusion and recommendation

Among the tested varieties, Melkasalsa gave the highest marketable yield (9.3 t ha^{-1}) followed by Cochoro (8.6 t ha^{-1}). The lowest unmarketable fruit yield was recorded from Metadel (2.5 t ha^{-1}) and Eshet (2.59 t ha^{-1}). Although Metadel and Eshet gave the lowest unmarketable fruit number and yield their overall yields were very low. Based on the results of the field experiment and farmers preference, Melkasalsa and Cochoro are recommended for Aberegelle area of Waghimera zone under irrigation. Improving soil fertility and other related crop management activities needs to be further worked to improve the productivity of tomato for the study area.

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Evaluation of micro-dosing fertilizer application on sorghum production in Wag-Lasta districts

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Abstract

A field experiment was conducted under rainfed conditions to evaluate micro-dosing application of N and P fertilizer on sorghum yields at Wag-Lasta, Amhara Region. The treatments were comprised of a factorial combination of three rates of recommended NP in micro dosing (25%, 50% and 75%) and three times of N application plus control (without fertilizer) and recommended NP. The experiment was laid down in a randomized complete block design with three replications. All DAP was applied at plating and urea was applied as per the treatment setup. Miskir sorghum variety was used as a test crop. Tie-ridging at 2 m interval was applied to all plots uniformly. Required data were collected and analyzed using SAS software and means were separated using least significant difference at 5% for significant treatment means differences. Application of 34.5 kg P_2O_5 ha^{-1} and 30.75 kg N ha^{-1} (N applied 1/3 at sowing, 1/3 at emergence and 1/3 first weeding or knee height) increased the grain yield by 122% over the control and 28.4% over the recommended NP and saves 25% of the recommended fertilizer at Aybra. While at Lalibela, application of 20.5 kg N ha^{-1} and 23 kg P_2O_5 ha^{-1} (N applied 1/3 at sowing, 1/3 at emergence and 1/3 at first weeding) increased the grain yield by 174% over the control and 15% over the recommended NP and saves 50% of the recommended fertilizer. Therefore, application of 75% of the recommended NP (N applied in three splits) is recommended for Aybra area and application of 50% of the recommended NP (N applied in three splits) for Lalibela area.

Keywords: application method, fertilizer, micro-dose, sorghum, Wag-Lasta

Introduction

Low level of soil fertility because of land degradation and nutrient depletion has been a critical challenge to agricultural production in Ethiopia. On cultivated land, there is a continuous decline in soil quality resulted from reduced fallows and sub-optimal use of fertilizer inputs. Continuous cultivation coupled with nutrient depletion, poor crop residue management, and reduced crop rotation resulted in poor soil fertility (Heluf, 2005). Most soils in the semi-arid areas of northeastern Ethiopia are heavily depleted of plant nutrients and are characterized by low total nitrogen, available phosphorus (P) and organic carbon (OC) contents leading to substantial decline in crop productivity (Asnakew, 1994).

Drought along with low soil fertility due to excessive degradation and nutrient depletion are serious limitations to crop production in Ethiopia (FAO, 1999). Sorghum is one of the leading food crops in Ethiopia that comprises 17% of the total cereal production in the country. It is the second major cereal crop next to teff (*Eragrostis tef*) in consumption and area coverage. Sorghum accounts more than 16% of the total cultivated area in the Amhara Region (CSA, 2014). It is the dominant crop in semi-arid areas such as Wag-Lasta areas in the Amhara Region. The average yield of sorghum per unit area is not more than 1.0 t ha^{-1} (CSA, 2014). Low , erratic and poorly distributed of the rainfall and poor soil fertility are some of the causes that limit crop productivity including sorghum in Ethiopian (Huluf, 2003).

Inorganic fertilizer is critically important to increase crop yield (Mwangi, 1995). Gruhnet al., (1995) suggested fertilizer rates must be increased to meet the ever increasing demand of food. Micro-dosing refers to the application of small quantities of fertilizer at planting time or as top dressing about three to four weeks after emergence. Micro-dosing fertilizer enhances fertilizer use efficiency and improves yields, while minimizing input and investment cost. This is an efficient way to apply fertilizer, because the fertilizer is applied adjacent to the seeds, thereby ensuring a high rate of uptake. Micro-dosing of fertilizers was found to increase yields by 44% to 120% and farmers' income by 52% to 134% compared to traditional application methods (Tabo et al., 2006). Similar research finding in Niger shows micro-dose method increased yield with low cost and efficient (Hayashi et al., 2008). Ncube et al. (2007) showed that farmers could increase their yields by 50% by applying about 9 kg of nitrogen per hectare compared to no application in Zimbabwe. In addition rational use of fertilizer plays its own role to mitigate climate change (Hailemariam et al., 2013). However, there is no information on fertilizer application in a micro dosing in Amhara region and the study area. Therefore, this research was designed to evaluate micro-dosing fertilizer application techniques (N and P) on sorghum yields at moisture stressed areas of Waghimra and North Wollo zones of Amhara region.

Materials and method

Description of the study areas

The study was conducted for two years at Aybera and Shimshaha areas of Waghimra and North Wollo zones of the Amhara Region; respectively (Figure 1). The location of the study areas was found within the range of altitude from 1921 to1947 m.a.s.l. The study areas are characterized with small (290 mm to700 mm) erratic annual rainfall.

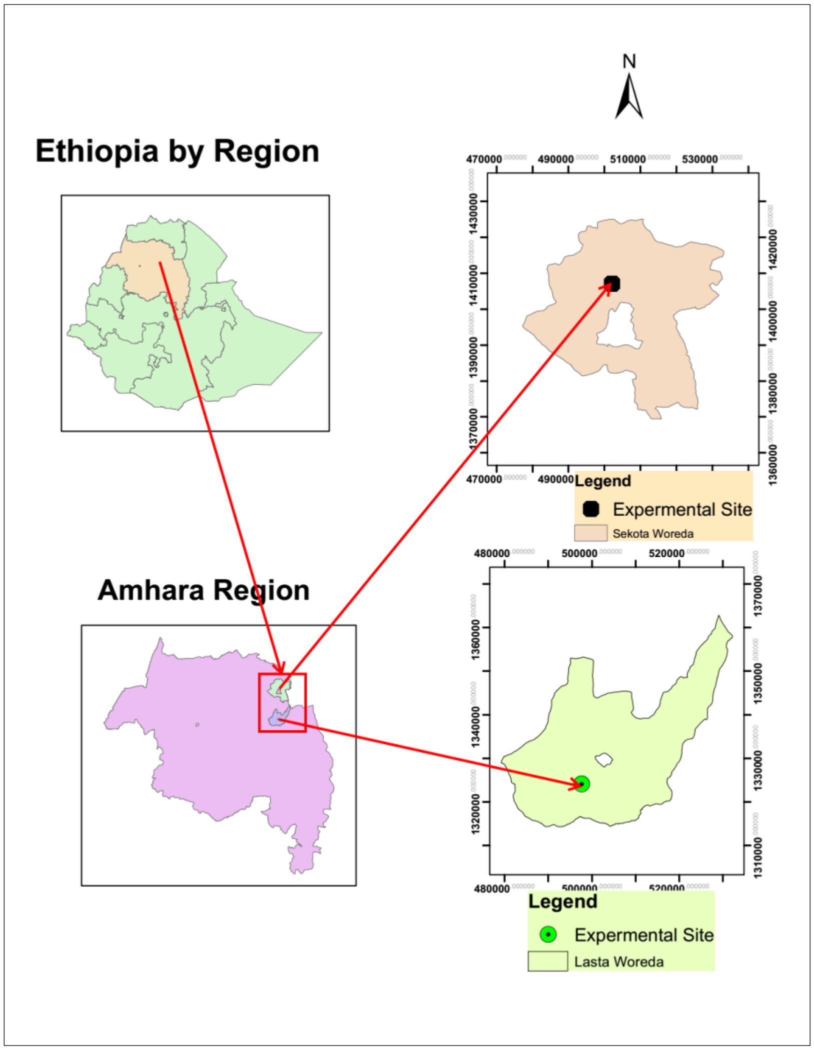

Figure 1. Location map of study area

Experimental design

The experiment was comprised of three rates of NP (25%, 50% and 75% of the recommended NP) factorialy combined with three nitrogen splitting times (1. half at sowing and half at emergence, 2. One third at sowing, One third at emergence and one third at first weeding (knee height), 3. Half at sowing and half at first weeding (knee height)) arranged in completely randomized block design (RCBD) with three replications. In addition, two treatments, control (without any nutrient) and recommended NP fertilizer were included and made a total of 11 treatments. DAP and urea were used as a source of phosphorus and nitrogen respectively. Each plot was having an area of 3.75m by 4m. The space between blocks was 1m while between plots was 0.5m. The space between plants and rows was 15 cm and 75 cm; respectively. Misker was sorghum variety was used as a test crop. Tie-ridge with 2 meter interval was uniformly applied. Similarly cultivation and weeding were done uniformly for all treatments.

Data analysis

Collected data were subjected to statistical analysis using SAS statistical software version 9.0 and treatment effects were compared using the Fisher's Least Significant Differences test at 5% level of significance.

Soil sampling and analysis

A composite soil sample was collected from 0-20 cm, air dried and passed through 2 mm sieve to determine most nutrients and through 0.5 mm for total nitrogen and organic carbon. The soil parameters were determined following standard laboratory procedures. Soil pH was determined in H_2O using 1:2.5 soils to solution ratio using a combined glass electrode pH meter (Chopra and Kanwar, 1976). Organic carbon of the soils was determined following the wet digestion method as described by Walkley and Black (1934) while percent organic matter of the soils was determined by multiplying the percent organic carbon value by 1.724. Total N was analyzed by the Kjeldahal digestion and distillation procedure (Bremner and Mulvaney, 1982).

Partial budget analysis

The partial budget analysis was done to evaluate the economic feasibility of nitrogen and phosphorus application based on the manual developed by CIMMYT (1988). The fertilizer cost, mean price of sorghum, labor cost for each fertilizer application was collected from the two districts. For the purpose of partial budget analysis, yields were adjusted downward by 10% from the exact yield.

Results and discussion

The soil pH of surface soil for Aybra and Lalibella was 6.3 and 6.4 respectively. Based on Tekalign, (1991), the reaction of the study areas is within slightly acidic class. The organic matter content of the soil was 1.0% for Aybra and 1.2% for Lalibella; which is extremely below the critical limit (3.45%). Similarly, the total nitrogen content was 0.01% for Aybra and 0.02% for Lalibella; which is extremely below the critical limit.

Effects on grain yield

The Maximum grain yield (2476.4 kg ha^{-1}) was obtained from 75% recommended NP (34.5 kg P_2O_5 and 30.75 kg N ha^{-1}, N applied in three splits) while the minimum grain yield (1114.8 kg ha^{-1}) was obtained from the control (without fertilizer) at Aybra. Micro-dosing application increased the yield by 122% over the control and by 28.4% over the recommended NP (Table 1) at Aybra. Similarly, the maximum grain yield (2807 kg ha^{-1}) was obtained from 50% NP (20.5 kg N ha^{-1} and 23 kg P_2O_5 ha^{-1} (N applied in three splits)) whereas the minimum yield (1023 kg ha^{-1}) was obtained from the control (without fertilizer) at Lalibela (Table 1). In addition to the yield advantages over the recommended NP, micro dose application saved 25% fertilizer at Aybra and 50% fertilizer amount at Lalibela. The saved fertilizer amounts can be used for additional sorghum production from 1/3 ha at Aybra and from one ha at Lalibela in micro dose application. Our result is inline with findings of Tabo et al., (2006) and Osman et al., (2009) who reported sorghum yield increment ranging between 44 to 120% compared to control using micro-dose application. Similarly, Twomlow et al., (2010) reported that application of micro-dose of 10 kg nitrogen ha^{-1} increased the yield by 30-100%. Three times split application of nitrogen with micro-dosing at: 1/3 at sowing, 1/3 at emergence and 1/3 at knee height was more efficient than the other application methods.

Effect on biomass yield

Significantly heigher biomass yield at Aybra was also obtained from 75% recommended NP (34.5 kg P_2O_5 and 30.75 kg N ha^{-1}, (N applied in three splits)) and the minimum biomass yield (4246.3 kg ha^{-1}) was obtained from the control (Table 1). Micro-dose application increased the biomass yield by 57% compared to the control and by 21.6% over the recommended NP at Aybra and by 85% over the control and 10% over the recommended NP at Lalibela. The results are in line with the findings of Tabo et al. (2006) , Osman et al. (2009) and Abdalla et al., (2015) who reported increased sorghum biomass due to micro-dose application.

Table1. Effect of nitrogen and phosphorus on yield and yield component of sorghum

DAP kg ha^{-1}	Urea kg ha^{-1}	Aybra						Lalibella					
		Grain yield kg ha^{-1}			Biomass yield kgha^{-1}			Grain yield kgha^{-1}			Biomass yield kgha^{-1}		
		Year-1	Year-2	Combined	Year-1	Year-2	combined	Year-1	Year-2	combined	Year-1	Year-2	combined
0	0	1324.1	905.6	1114.8	4548.1	3944.4	4246.3	1573.9	472.2	1023.1	5933.5	1944.4	3939
25	12.5 SE	1116.7	1911.1	1513.9	7225.3	6111.1	6443.1	1977.8	555.6	1266.7	7186.7	1333.3	4260
25	12.5 SEF	1738.1	1662.2	1700.15	5572.5	5611.1	5591.8	1952.5	616.7	1284.6	7248.9	2777.8	5013
25	12.5 SFW	1535.0	1861.1	1698.05	6486.5	5555.6	6021.0	1830.0	1026.6	1427.3	7775.2	3055.6	5415
50	25SE	1760.0	2277.8	2018.9	5920.0	5833.3	5876.7	2833.6	1311.1	2072.4	10767	3222.2	6995
50	25 SEF	2143.9	1777.8	1960.8	6216.9	5740.7	5978.8	2715.6	2900.0	2807.8	9863.1	4722.2	7293
50	25 SFW	1960.3	2066.7	2013.5	7672.2	3888.9	5780.6	2101.9	2002.3	2045.1	8622.8	2500.0	5561
75	37.5 SE	1540.8	2738.9	2139.9	6090.0	5000.0	5545.0	2329.6	2577.8	2453.7	9581.9	5185.2	7384
75	37.5 SEF	2158.7	2794.4	2476.6	7219.4	5666.7	6668.2	2148.7	1700.0	1924.4	8628.1	5277.8	6953
75	37.5 SFW	1816.5	2272.2	2044.4	5767.5	4111.1	4939.3	2017.8	2250.0	2133.9	8388.3	3888.9	6139
100	50	1952.2	1905.6	1928.9	6193.5	4777.8	5485.6	2280.6	2594.4	2437.5	8804.1	4444.4	6624
CV (%)		12.89	15.23	21.47	9.54	13.22	17.73	7.73	11.92	24.74	10.3	14.87	27.82
LSD (0.05)		380.25	535.52	474.2	1012.5	1144.6	1167.2	288.47	362.02	572.01	1464.3	878.06	3298.6

SE stands for urea application at sowing and at emergence; SEF stands for urea application at sowing, at emergence and at first weeding, SFW stands for urea application at sowing and at first weeding(knee height)

Partial budget analysis

Partial budget analysis of Aybra shows that application of 75% recommended NP (34.5 kg P_2O_5 and 30.75 kg N ha^{-1} N applied in three splits) had the highest net benefit (1505.07 ETB ha^{-1}) with 1505% MRR at Aybra (Table 2). Whereas the partial budget analysis for Shumsha shows that application of 50% recommended NP (20.5 kg N and 23 kg P_2O_5 ha^{-1} N applied in three splits) resulted in the highest net benefit (17844.01 ETB ha^{-1}) (Table 3) with MRR of 1822%.

Table2. Partial budget analysis for Aybra

DAP kg ha^{-1}	Urea kg ha^{-1}	Unadjusted yield (kg ha^{-1}	Adjust yield (kg ha^{-1})	Total variable cost (ETB)	Gross benefit (ETB)	Net benefit (ETB)	MRR%
0	0	1114.8	1003.32	0	7023.24	7023.24	
25	12.5 SE	1513.9	1362.51	633.76	9537.57	8903.81	D
25	12.5 SEF	1700.15	1530.135	647.76	10710.945	10063.185	469
25	12.5 SFW	1698.05	1528.245	633.76	10697.715	10063.955	D
50	25 SE	2018.9	1817.01	1085.64	12719.07	11633.43	359
50	25 SEF	1960.8	1764.72	1099.64	12353.04	11253.4	D
50	25 SFW	2013.5	1812.15	1085.64	12685.05	11599.41	D
75	37.5 SE	2139.9	1925.91	1537.51	13481.37	11943.86	69
75	37.5 SEF	2476.6	2228.94	1551.51	15602.58	14051.07	1505
75	37.5 SFW	2044.4	1839.96	1537.51	12879.72	11342.21	D
100	50	1928.9	1736.01	1876.94	12152.07	10275.13	D

SE stands for urea application at sowing and at emergence; SEF stands for urea application at sowing, at mergence and at first weeding, SFW stands for urea application at sowing and at first weeding (knee height).

Table 3. Partial budget analysis for Lalibella

DAP kg ha^{-1}	Urea kg ha^{-1}	Unadjusted yield (kg ha^{-1}	Adjust yield (kg ha^{-1})	Total variable cost (ETB)	Gross benefit (ETB)	Net benefit (ETB)	MRR%
0	0	1023.1	920.79	0.0	6905.93	6905.93	
25	12.5 SE	1266.7	1140.03	623.8	8550.23	7926.46	164
25	12.5 SEF	1427.3	1284.57	634.3	623.76	9010.51	332
25	12.5 SFW	1284.6	1156.14	656.8	8671.05	8014.29	D
50	25 SE	2072.4	1865.16	1075.6	13988.70	12913.06	864
50	25 SEF	2807.8	2527.02	1108.6	18952.65	17844.02	1822
50	25 SFW	2045.1	1840.59	1304.4	1075.64	12728.79	D
75	37.5 SE	2453.7	2208.33	1527.5	16562.48	15034.96	671
75	37.5 SEF	2133.9	1920.51	1527.5	14403.83	12876.31	D
75	37.5 SFW	1924.4	1731.96	1560.5	12989.70	11429.19	D
100	50	2437.5	2193.75	1883.9	16453.13	14569.18	D

SE stands for urea application at sowing and at emergence; SEF stands for urea application at sowing, at mergence and at first weeding, SFW stands for urea application at sowing and at first weeding (knee height).

Conclusion and recommendation

Micro-dosing application for sorghum was found very important to increase the production and productivity of sorghum. Results from this study confirm that micro-dosing increased sorghum yields than drilling in rows. At Aybra, 75% of the recommended urea and DAP increased sorghum yield by 28.4% and 50% of the recommended urea and DAP increased sorghum yield by 15% over the recommended NP. Micro-dosing fertilizer application is simple and cheap with low risk to resource-poor farmers in the dry areas of Wag-Lasta. Therefore, application of 75 kg DAP and 66.8 kg urea (applied in three splits) ha^{-1} for Aybra and 50 kg DAP ha^{-1} and 44.6 kg urea (applied in three splits) ha^{-1} for Lalibela are recommended for higher sorghum yield and economic utilization of fertilizers.

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Performance of Improved Maize Varieties under Irrigation for Grain Production at Koga Irrigation Scheme, West Gojam, Amhara Region.

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Abstract

Maize is one of the most important food crops in Amhara region. It provides high grain yield under irrigation compared to rain-fed. The trial was conducted with the objective of identifying and recommending adaptable and high yielding improved maize varieties that suit to the irrigation environments. Twelve hybrids and six open pollinated maize varieties were studied as a two sets of experiment in randomized complete block design with three replications. The plots were irrigated using furrow irrigation every 14 days. Urea and DAP were used as nitrogen and phosphorus sources respectively. All agronomic managements were applied uniformly to all plots. Data were collected and analyzed using SAS statistical software and different treatment means were separated using least significant difference at 5%. The result revealed that varieties showed high genetic variation among themselves for most traits. Shone variety gave the highest grain yield (13458 kg ha^{-1}) followed by PHB3253 (Jabi) (13320 kg ha^{-1}) in 2013/14 with no significant difference between them. While in 2014/15, the highest grain yield was obtained from BH-660 (10747 kg ha^{-1}) and AMH-760Q (10567 kg ha^{-1}). Averaged over years, Shone gave the highest grain yield (11486 kg ha^{-1}) followed by AMH-760Q (11277 kg ha^{-1}). Similarly, Gibe-1 (OPV) gave the highest grain yield 11673.8 kg ha^{-1} in 2013/14, 10093.1 kg ha^{-1} in 2014/15 and 10883.4 kg ha^{-1} averaged over years. The grain yield performance of most tested varieties under irrigation was higher than their grain yield performance under rain-fed condition. Under irrigation, Shone variety gave 35.1 % and Gibe-1 variety 39.5% yield advantage over the rain-fed. Therefore, Shone and Gibe-1 are recommended as potential improved varieties under irrigation for grain yield whereas AMH-760Q as potential quality protein for Koga irrigation scheme and similar environments.

Key words: grain production, hybrid, irrigation, open pollinated, maize,

Introduction

Maize (*Zea mays* L.) is one of the most important strategic cereal crops in Ethiopia in-terms of food security. It ranks second in area coverage next to teff and first both in total production and productivity (CSA, 2014). Out of 79.38 % crop area covered by cereals, maize took up 16.08 % of land. Maize contributed 17.57 % to the total Cereal production of 85.51% of the grain production (CSA, 2014). Maize is used for food, feed, fuel and fibers and a good source of carbohydrate when it used as food and feed.

Both hybrid and open pollinated maize varieties are cultivated in the region. Hybrid maize varieties are high yielder and more uniform for mechanization compared to open pollinated. Only seed of hybrids is produced and distributed to maize producers in Amhara region and no seed of improved open pollinated maize varieties is produced and disseminated. But improved high yielding open pollinated maize varieties have considerable importance in areas where seed industry is not well developed and they are also better options in the context of resource poor farmers who cannot afford the hybrid seeds and are inclined towards use of recycled seeds. In addition to these facts open pollinated maize varieties provided comparable yield to hybrids in low potential environments and under stress conditions.

More over farmers in the region use the seed of local open pollinated maize varieties and second generation of hybrid seed for production. Amhara Region Bureau of Agriculture maize production and marketing plan (2017) stated that from the total land covered by maize in the region only 38% planted by certified hybrid seed. The remaining more than 60% of the land was cultivated by local open pollinated and the second generation of hybrid seed. The main reason for the coverage of large portion of maize land by the local open pollinated and second generation hybrid varieties are the cost of certified seed and fertilizers mostly relatively higher than the price of the grain. Open pollinated maize varieties are economical options for resource poor farmers when the price of the hybrid seed and fertilizer are relatively higher than the price of the grain (Kevin and Baenziger, 2001).

Maize production under irrigation provide better yield as compared to rain fed production for controlled amount of water supplied by irrigation at the required growth stages of the crop. Boshev et al., (2014) and Jacob et al., (2014) have proved that maize varieties produced high grain yield under irrigation but might not be good yielder in rain fed production. The authors concluded that maize varieties with high and stable yields could be expected only with irrigation.

Improved maize varieties developed or adapted to the irrigation environment are also other detrimental factors to increase the production and productivity of maize. Selecting improved maize varieties that have a high yield potential, good disease and insect tolerance, good resistance to lodging and a maturity length that suit the irrigation environmental conditions are very crucial to improve maize production. So far, no maize varieties have been developed for irrigation system in Ethiopia in general and in Amhara Region in particular. Improved maize varieties cultivated in the region as well as in the country were also not evaluated for green cobs. As maize is one of the strategic crops for assuring food security, its production under irrigation and development of irrigated maize varieties are fundamental to increase maize production. Therefore, the study was carried out to identify and recommend adaptable, high yielding improved maize varieties that suit to the irrigation environment.

Materials and Methods

The experiment was conducted at Koga irrigation scheme for two years (2013/14 and 2014/15). Koga irrigation command area is located in Mecha District; 41 kilometres away from Bahir Dar on the way to Addis Ababa via Debre Markos. Geographically, the site was located at 37°7'29.721" E and 11°20'57.859" N at an altitude of 1953 m a.s.l. The average annual rainfall of the area was about 1118 mm and the mean maximum and minimum temperatures were 26.8 ^{0}C and 9.7 ^{0}C respectively. Twelve hybrid and six open pollinated maize varieties from diverse backgrounds and maturity groups (Table 1) were planted in two sets in a randomized complete block design with three replications. The plot size was 5.1m by 3.75m (19.125m^2) and contained five rows. The distance between rows was 0.75 m with the hills spaced at 0.3 m. The plots were planted to two seeds per hill and thinned to obtain 44444 plants per hectare. The recommended seed rate (25 kg ha^{-1}) and fertilizer rates (200 kg urea ha^{-1} and 200 kg DAP ha^{-1}) were used in the experiment. The whole amount of DAP was applied at planting while urea was spilited into half at planting and the remaining half at knee height. The trial was irrigated using furrow irrigation every 14 days. Weeding and hoeing were carried out according to the standard cultural practices. Data were collected for different traits including plant height, ear height, grain yield, days to 50% silking, days to 50% tasseling, ear diameter, ear length, ear aspects and number of cobs.

The central three rows from each plot were harvested at maturity and the fresh ear weight was measured in each plot. Grain yield data was calculated from the fresh ear weight of three central rows of each plot by adjusting to 13 percent moisture content and subjected to analysis of variance (ANOVA) using SAS version 9.0. To satisfy assumptions of analysis of variance, all variables were subjected to the Levene test of homogeneity of variance and to the Shapiro-Wilk W test of normality and the least significant differences among means were calculated to identify differences among treatments.

Table 1. Description of hybrid maize varieties tested and their adaptation

No	Hybrids	Maize type	Source	Adaptation (meter asl)
1	BHQPY543	Non-QPM	Bako ARC	1000-1800
2	BHQPY545	QPM	Bako ARC	1000-2000
3	BH660	Non-QPM	Bako ARC	1600-2200
4	BH661	Non-QPM	Bako ARC	1600-2200
5	AMH-760Q	QPM	Ambo ARC	1800-2600
6	PHB3253	Non-QPM	Pioneer seed	1000-2000
7	AMH850	Non-QPM	Ambo ARC	1800-2400
8	AMH851	Non-QPM	Ambo ARC	1800-2600
9	AMH800	Non-QPM	Ambo ARC	1800-2600
10	SHONE	Non-QPM	Pioneer seed	1000-2000
11	BH-140	Non-QPM	Bako ARC	1000-1800
12	BH-540	Non-QPM	Bako ARC	1000-1800
	Open pollinated			
13	Gibe-1	Non-QPM	Bako ARC	1000-1800
14	Gibe-2	Non-QPM	Bako ARC	1000-2000
15	Kuleni	Non-QPM	Bako ARC	1600-2200
16	Guto	Non-QPM	Bako ARC	1600-2200
17	Hora	Non-QPM	Ambo ARC	1800-2600
16	Alemeya composite	Non-QPM	Haromya university	1000-2000

Note: QPM= Quality Protein Maize.

Results and discussions

Genetic variability among genotypes is vital to develop and identify adapted, high yielding and biotic and abiotic factors resistant or tolerant varieties. The analysis of variance mean squares revealed significant differences among hybrid maize varieties for most of the traits measured in both seasons (Table 2 and 3). This variation could be attributed to genetic, environmental effects and the interaction of the two. The phenotypic performance of the genotypes is the result of variation due to genetic, environment and the interaction of the two (Melkamu and Molla, 2016 and Farshadfar *et al*, 2013). Moreover, the results of the analysis showed highly significant differences among the mean values for most traits. Different researchers have reported significant variability in different maize varieties including hybrids, top-crosses and open pollinated varieties (Idris and Mohammed, 2012; Melkamu *et al*, 2014).

1. *Performance of hybrid maize varieties under Irrigation*

Hybrid maize varieties have shown plenty of potentials to different traits due to hybrid vigor (hetrosis) in 2013/14 off season (Table 2). Heterosis is the main genetic contributor for variation among genotypes and for their traits that provides better performance for hybrids (Bidhendi *et al*, 2012 and Rajendran *et al, 2014*). The highest number of cobs (83370 cobs ha^{-1}) was obtained from BHQPY-545 indicating multi-ear (prolific) genetic potential of the variety. A variety producing more number of cobs per plant and per hectare had high prolific (producing more cobs) genetic potential (Martin *et al*, 2006). The longest cob (with the average cob length of 19.9 cm) was produced by BH-661 revealing its genetic quality for giving long cobs but not significantly different from AMH-851, AMH-850, PHB-3253, AMH-800, BH-660 and Shone. Cob girth is one of the main yield component traits. PHB-3253 (Jabi) gave higher average cob diameter of 5.8 cm followed by Shone, BH-140 and AMH-850 (Table, 2). Shone gave the highest grain yield (13458 kg ha^{-1}) followed but at par by PHB-3253 (Jabi) (13320kg ha^{-1}).

Table 2. Mean performance of twelve hybrid maize varieties for yield and yield related traits under irrigation in 2013/14 off season.

Ent no.	Variety	PH (cm)	EH (cm)	DT	DS	CL (cm)	CD (cm)	CN ha^{-1}	GY kg ha^{-1}
1	BHQPY-545	238.0^{CDE}	138.2^{FG}	114.3^{A}	117^{AB}	14.3^{E}	4.8^{C}	83370^{A}	8504^{D}
2	BH-140	253.7^{CD}	167.5^{BCD}	113.0^{A}	117.7^{A}	15.6^{ED}	5.2^{BC}	52288^{BCD}	12140^{ABC}
3	BH-543	253.0^{CDE}	153.5^{CDEF}	112.0^{A}	117.7^{A}	18.3^{AB}	4.9^{BC}	56064^{BC}	11975^{ABC}
4	BH-540	257.3^{BCD}	154.3^{CDEF}	112.3^{A}	116.7^{AB}	15.9^{EDC}	5.1^{BC}	46768^{BCD}	9991^{CD}
5	SHONE	256.3^{BCD}	139.5^{FG}	105.7^{CD}	112.0^{CDE}	18.3^{AB}	5.2^{BC}	41830^{D}	13458^{AB}
6	BH-660	288.0^{A}	186.4^{AB}	112.3^{A}	118.0^{A}	18.7^{AB}	5.1^{BC}	47059^{BCD}	10033^{BCD}
7	AMH-760Q	260.7^{BC}	168.9^{ABC}	106.3^{BCD}	113.7^{ABCD}	17.6^{BDC}	5.0^{BC}	46768^{BCD}	11988^{ABC}
8	BH-661	281.3^{AB}	189.0^{A}	111.3^{AB}	116.7^{AB}	19.9^{A}	5.1^{BC}	54321^{BCD}	11406^{BCD}
9	AMH- 850	226.3^{E}	135.5^{FG}	101.3^{DE}	109.3^{CDE}	18.9^{AB}	5.2^{BC}	45606^{CD}	11621^{ABCD}
10	AMH- 800	259.7^{BCD}	161.4^{CDE}	100.3^{E}	108.7^{DE}	19.0^{AB}	5.1^{BC}	55483^{BC}	12197^{ABC}
11	AMH- 851	254.7^{BCD}	146.8^{EFG}	102.0^{DE}	107.3^{E}	18.5^{AB}	4.8^{C}	51416^{BCD}	10824^{BCD}
12	PHB-3253	233.3^{DE}	126.5^{G}	101.3^{DE}	107.3^{E}	18^{ABC}	5.8^{A}	48221^{BCD}	13320^{ABC}
CV (%)		**6.3**	**7.8**	**2.87**	**2.63**	**7.4**	**5.6**	**14.2**	**17.2**
LSD (0.05)		**26.99**	**20.51**	**5.23**	**5.05**	**2.2**	**0.48**	**9510.6**	**3430.9**

Where, PH = Plant height, EH = Ear height, DT = Days to 50% tasseling, DS = Days to 50% silking, CN = Cob number, EAS = Ear aspect, CL = Cob length, CD = Cob diameter and GY = Grain Yield

There was also significant difference in yield and yield parameters among the hybrid maize varieties in 2014/15 (Table 3). This difference depicts the existence of genetic variation for improvement. Large number of cobs was produced by AMH-760Q (49383 cobs ha^{-1}) followed by AMH-800 (41830 cobs ha^{-1}) at par with AMH-850 and AMHQPY-545. Shone and BH-660 also provided longest cobs but not significantly different from PHB-3253, AMH-851, BH-140, AMH-850, BH-661 and BH-540. Shone gave the higher cob diameter (5.7 cm) followed by PHB-3253 (Table 3). Similarly, Shone had excellent ear aspect with ear aspect value of one. In year two (2014/15) the highest grain yield was obtained from BH-660 (10747 kg ha^{-1}) followed by AMH-760Q (10567 kg ha^{-1}) which had grain yield at par with BH-543, Shone, BH-661, AMH-850, AMH-800 and PHB-3253(Table 3). The result is in agreement with the findings of Bidhendi *et al*, 2012 and Rajendran *et al, 2014* who reported that hybrids varieties are preferred for their high yield potential due to heterosis, a manifestation of the superiority of hybrid performance. The grain yield produced by the improved varieties under irrigation was higher than the yield under the rain-fed system (Jacob et al., 2014 and Melkamu et al., 2014).

Crop performance is the result of the genetic potential of the crop, the environment and the interaction of the two. Large number of cobs was produced by BHQPY-545 (49274) across years followed by AMH-760Q. BH-661 (18.1 cm), BH-660 (17.9 cm) and Shone (17.9) provided longest cobs over the two years showing their genetic potential. Hybrid maize Shone, AMH800, AMH851, AMH850 and PHB3253 were also produced long cobs over years and showed similar performance with BH-661. Similarly, BH-660, Shone and PHB-3253 gave large cob diameter. Maize grain yield is a complex trait which is affected by genetic, environment and their interaction. The result indicated that Shone and AMH-760Q produced the highest grain yield per hectare providing 11486 kg and 11277 kg grain yield respectively. The grain yield performance of these two maize hybrids under irrigation was much higher than their performance in the rainfed system. The evaluation of eight hybrid maize varieties in rain-fed condition for two years in Jabitehinan and South Achefer districts indicated that grain yield potential of Shone was 8500 kg ha^{-1} (Melkamu et al, 2014). According to this result, Shone had 2986 kg (35.1%) yield advantage under irrigation. Jacob et al. (2014) indicated that maize production under irrigation was much higher than rain fed by average yield of 4500 kg ha^{-1}.

Table 3. Mean performance of twelve hybrid maize varieties for yield and yield related traits under irrigation in 2014/15 off season.

Ent no	Variety	GY (Kg ha^{-1})	PH (cm)	EH (cm)	DT	DS	EL	ED	CN ha^{-1}	EAS
1	BHQPY-545	7179^{BC}	170.0^{F}	94.0^{D}	98^{BC}	101^{BC}	11.8^{E}	4.8^{CD}	36020^{AB}	1.7^{BCD}
2	BH-140	6532^{C}	209.7^{CDE}	118.7^{BCD}	103^{A}	108.3^{A}	14.4^{ABCDE}	5.0^{BC}	29920^{B}	2.0^{ABC}
3	BH-543	7226^{ABC}	223.3^{BC}	127^{ABC}	103^{A}	108.3^{A}	11.9^{DE}	4.8^{CD}	33115^{B}	2.3^{AB}
4	BH-540	6372^{C}	217.7^{BCD}	124.7^{ABC}	98^{BC}	100.3^{CD}	14.9^{ABCDE}	5.1^{B}	31373^{B}	2.7^{A}
5	SHONE	9513^{ABC}	238.3^{AB}	131.7^{AB}	98^{BC}	100.7^{BCD}	17.6^{A}	5.7^{A}	33696^{B}	1.0^{D}
6	BH-660	10747^{A}	260.3^{A}	134.0^{AB}	91^{D}	98^{D}	17.1^{A}	4.9^{BCD}	33696^{B}	1.8^{ABCD}
7	AMH-760Q	10567^{AB}	220.0^{BC}	146.3^{A}	95^{C}	101^{BC}	13.3^{CDE}	4.9^{BCD}	49383^{A}	2.3^{AB}
8	BH-661	8714^{ABC}	234.3^{ABC}	144.0^{A}	91^{D}	98.7^{CD}	16.4^{ABC}	4.8^{CD}	34277^{B}	1.2^{CD}
9	WONCHI	9128^{ABC}	186.3^{EF}	109.3^{BCD}	91^{D}	98.7^{CD}	15.1^{ABCDE}	4.7^{DE}	40087^{AB}	1.8^{ABCD}
10	ARGENI	8563^{ABC}	221.3^{BC}	129.3^{AB}	91^{D}	98.3^{CD}	13.1^{CDE}	4.4^{E}	41830^{AB}	1.8^{ABCD}
11	JIBAT	7093^{BC}	191.0^{DEF}	110.3^{BCD}	103^{A}	108.7^{A}	16.9^{AB}	4.8^{CD}	29630^{B}	2.2^{AB}
12	PHB-3253	8247^{ABC}	191.3^{DEF}	103.0^{CD}	99.7^{B}	103.3^{B}	15.6^{ABCD}	5.4^{A}	29049^{B}	2.0^{ABC}
CV (%)		**25.01**	**7.7**	**11.9**	**1.44**	**1.67**	**14.8**	**3.37**	**23.7**	**26.2**
LSD (0.05)		**35.3**	**27.8**	**24.7**	**2.37**	**2.88**	**3.7**	**0.28**	**14140**	**0.84**

Where, PH= Plant height, EH= Ear height, DT= Days to 50% tasseling, DS= Days to 50% silking, CN = Cob number per hectare, EAS= Ear aspect, ED = Ear Diameter, GY = Grain yield, EL = Ear Length

Table 4. Combined mean performance of twelve hybrid maize varieties for yield and yield related traits for 2013/14 and 2014/15

Entry no	Variety	GY (Kg ha^{-1})	PH (cm)	EH (cm)	DT	DS	EL	ED	CN ha^{-1}	EAS
1	BHQPY-545	7841^{D}	204^{F}	116.1^{G}	106^{AB}	109^{B}	13.1^{C}	4.79^{C}	49274^{A}	2.08^{ABC}
2	BH-140	9336^{ABCD}	231.7^{CD}	143.1^{CDE}	108^{A}	113^{A}	15.0^{BC}	5.1^{B}	34568^{BCD}	2.17^{ABC}
3	BH-543	9601^{ABCD}	238.2^{CD}	140.2^{DE}	107.5^{AB}	113^{A}	15.1^{BC}	4.9^{BC}	37572^{BCD}	1.92^{BC}
4	BH-540	8182^{CD}	237.5^{CD}	139.5^{DEF}	105^{BC}	108.5^{B}	15.4^{B}	5.1^{B}	33224^{D}	2.50^{A}
5	SHONE	11486^{A}	247.3^{BC}	135.6^{DEF}	101.8^{D}	106.3^{BCD}	17.9^{A}	5.5^{A}	32534^{D}	1.08^{E}
6	BH-660	10390^{ABC}	274.2^{A}	160.2^{AB}	101.7^{D}	108^{BC}	17.9^{A}	5.6^{A}	34595^{BCD}	1.67^{CD}
7	AMH-760Q	11277^{A}	240.3^{BCD}	157.6^{ABC}	101^{D}	107.3^{BC}	15.5^{B}	4.9^{BC}	42229^{AB}	2.00^{ABC}
8	BH-661	10060^{ABCD}	257.8^{AB}	166.5^{A}	101.2^{D}	107.7^{BC}	18.1^{A}	4.9^{BC}	37509^{BCD}	1.25^{DE}
9	AMH850	10375^{ABC}	206.3^{EF}	123.9^{G}	96.2^{E}	104^{DE}	17.0^{AB}	4.9^{BC}	37146^{BCD}	2.33^{AB}
10	AMH-800	10380^{ABC}	240.5^{BCD}	145.4^{BCD}	95.7^{E}	103.5^{E}	16.1^{AB}	4.79^{C}	41721^{ABC}	2.08^{ABC}
11	AMH-851	8959^{BCD}	222.8^{ED}	128.6^{EFG}	102.5^{CD}	108^{BC}	17.7^{A}	4.84^{BC}	34096^{CD}	2.42^{AB}
12	PHB-3253	10784^{AB}	212.3^{EF}	114.7^{G}	100.5^{D}	105.3^{DE}	16.8^{AB}	5.6^{A}	32607^{D}	2.25^{AB}
CV (%)		20.1	6.87	9.73	2.33	2.22	11.37	5.29	18.74	23.2
LSD (0.05)		2311	18.7	15.7	2.76	2.77	2.15	0.31	8116	0.53

Where, PH = Plant height, EH = Ear height, DT = Days to 50% tasseling, DS = Days to 50% silking, CN = Cob number, EL = Ear Length, ED = Ear Diameter, EAS = Ear aspect

2. *Performance of Open Pollinated Maize Varieties under Irrigation*

Genetic variation is the base for the development of new improved varieties and identification of adapted varieties. Significant variations were observed among open pollinated maize varieties for number of cobs, grain yield, ear aspect, days to 50% silking and days to 50% tasseling in 2013/14 irrigation season (Table 5). However, there was no significant difference observed among open pollinated maize varieties for plant height, ear height, cob length and cob diameter.

Grain yield is the final product of many multiplexes morphological and physiological processes takes place during the growth and development of crop. Grain yield ranged from 11673.8 kg ha^{-1} for Gibe-1 to 8041 kg ha^{-1} for Kuleni. Gibe-1 was the highest yielding open pollinated maize variety followed by Alemaya composite giving a grain yield of 11673 kg ha^{-1} and 10718 kg ha^{-1}

respectively. Melkamu and Molla (2016) investigated that grain yield mean performances indicated significant differences among open pollinated maize varieties. They added that the evaluation of open pollinated maize varieties in rain fed condition indicated that Gibe-1 provided 8800 kg ha^{-1} at South Achefer and 7800 kg ha^{-1} average yield across testing environments.

Table 5. Mean performance of six open pollinated maize varieties for yield and yield related traits in 2013/14 off season

Variety	PH (cm)	EH (cm)	DT	DS	EL (cm)	ED (cm)	CN ha^{-1}	GY (kg ha^{-1})	EAS
Gibe-1	256.7	157.4	105^{AB}	112^{B}	18.5	5.8	46478^{B}	11673.8^{A}	1.8^{AB}
Gibe-2	234.0	135.6	103.7^{AB}	111^{B}	18.5	5.5	67974^{A}	9697.6^{ABC}	1.2^{B}
Hora	231.0	143.9	98.7^{B}	107^{B}	19.1	5	50835^{B}	8783.5^{BC}	2.7^{A}
Guto	233.3	139.2	109.3^{A}	117.7^{A}	16.9	5.3	70007^{A}	8333.8^{C}	1.8^{AB}
Alemaya composit	254.3	156.4	104^{AB}	111^{B}	19.1	5.5	41540^{B}	10718.0^{AB}	1.3^{AB}
Kuleni	250.3	157.6	98^{B}	107^{B}	18	5	50254^{B}	8041.0^{C}	2.0^{AB}
Cv (%)	5.7	7.9	3.7	2.6	4.5	6.3	16.82	12.1	25.6
LSD (0.05)	NS	NS	6.98	5.17	NS	NS	16682	2099.3	0.84

Where, PH = Plant height, EH = Ear height, DT = Days to 50% tasseling, DS = Days to 50% silking, CN = Cob number, EAS = Ear aspect, ED = Ear Diameter, GY = Grain yield, EL = Ear Length

Open pollinated maize varieties produced high grain yield and even statistically comparable with most commercial maize hybrids (Malik et al, 2010). SARE (2004) evaluated open pollinated maize, synthetic population and varietal hybrids and indicated no significant difference for grain yield between open pollinated and varietal hybrids. This shows that open pollinated maize can produce comparable yield to hybrid maize varieties especially in low potential environment.

The highest cob number was produced by Guto (70007 cobs ha^{-1}) followed by Cibe-2 (67974 cobs ha^{-1}). Cob number per plant and cob number per plot as well as cob number per hectare are not always positively correlated with weight of grains which directly indicates the yielding ability of the variety.

Significant mean difference was observed among open pollinated maize varieties for all traits including grain yield in 2014/15 irrigation season (Table 6). Melkamu and Molla, 2016 reported that open pollinated maize varieties displayed disparities for grain yield and yield components; Hence, Gibe-1 produced the highest grain yield with desirable stability. Ear length varied from 15.7 cm for Alemaya composite and Kuleni to 11.1 cm for Guto. The highest cob length obtained from Alemaya composite and Kuleni indicating their genetic yield potential. Ear diameter for open pollinated maize varieties ranged from 5.4 cm for Gibe-2 to 4.5 cm for Hora. Higher ear diameter was produced by Gibe-1 and Gibe-2. Gibe -1 produced cobs with good ear aspect (Table 6).

The grain yield performance of open pollinated maize varieties was highly significantly different in 2014/15 (Table 6). The highest grain yield was produced by Gibe-1 (10093.1 kg ha^{-1}) followed by Gibe-2 (7913.8 kg ha^{-1}). The result in high yielding potential of open pollinated maize varieties is in line with the study reports made by many authors (Omandi *et al*, 2014; Melkamu and Molla, 2016 and Kutka, 2011).

The performance of open pollinated maize varieties combined over years (2013/14 and 2014/15) revealed that there was genetic differences among the varieties for all traits (Table 7). Years also showed significant differences for all traits except days to 50% silking indicating the performance of the open pollinated maize varieties was not consistent from year to year. The genotype by year interaction was statistically significant for grain yield, ear length, days to 50% silking, cob number and ear aspect disclosing the open pollinated maize varieties performed differently in different years. The result is in accordance with Melkamu and Molla (2016) who reported that the performance of open pollinated maize varieties influenced by the variation among them, environment variation and genotype by environment interaction.

Green cobs of maize can be consumed in a variety of forms, either fresh in roasted (boiled) or as an ingredient in cakes, ice-creams and a number of other foods (Silva, 2010 and Almeida *et al*, 2005). Production of green cobs is more profitable than grain production and harvested in short period compared to the grain harvesting time (Silva et al., 2010; Almeida *et al*, 2005). Cob length, cob diameter, cob number and ear aspect are some of the traits used to identify good grain cobs. Hence, Gibe-1 followed by Gibe -2 produced cobs with higher ear diameter 5.5 cm and 5.4 cm respectively. Higher cob number ha^{-1} (61226) was obtained from Gibe-2 followed by

Guto (55817). Cobs with better ear aspect were also obtained from Gibe-1 (1.83) followed by Gibe-2 (1.75) (Table 7).

Table 6. Mean performance of six open pollinated maize varieties for yield and yield related traits in 2014/15 off season

Variety	GY (Kg /ha)	PH (cm)	EH (cm)	DT	DS	EL	ED	CN ha^{-1}	EAS
Gibe-1	10093.1^{A}	249.7^{A}	159.7^{A}	106.3^{AB}	110.0^{AB}	13.2^{AB}	5.1^{AB}	49092^{AB}	1.8^{C}
Gibe-2	7913.8^{B}	187.0^{C}	117.3^{D}	105.7^{AB}	109.0^{B}	10.6^{B}	5.4^{A}	54321^{A}	2.3^{AB}
Hora	5078.1^{C}	197.7^{C}	120.7^{CD}	104.3^{B}	108.0^{B}	15.7^{A}	4.5^{D}	42411^{ABC}	2.7^{A}
Guto	4987.6^{C}	196.3^{C}	115.7^{D}	109.7^{A}	112.7^{A}	11.1^{B}	4.7^{CD}	41540^{ABC}	2.7^{A}
Alemaya composite	6427.9^{BC}	236.0^{AB}	156.0^{AB}	104.3^{B}	109.0^{B}	15.7^{A}	5.0^{ABC}	36311^{BC}	2.7^{A}
Kuleni	5073.6^{C}	219.7^{B}	137.0^{BC}	107.7^{AB}	113.0^{A}	15.7^{A}	4.8^{BDC}	27306^{C}	2.0^{BC}
CV (%)	17.3	4.6	7.8	2.1	1.5	11	4.9	21.1	10.7
LSD (0.05)	2084.6	18.1	19.2	4.1	3.1	2.7	0.44	16129	0.45

Where, PH = Plant height, EH = Ear height, DT = Days to 50% tasseling, DS = Days to 50% silking, CN = Cob number, EAS = Ear aspect, ED = Ear Diameter, GY = Grain yield, EL = Ear Length

Combined over years, the highest grain yield was obtained from Gibe-1 (10883.4 kg ha^{-1}) followed by Gibe-2 (8805.7 kg ha^{-1}) while the lowest was obtained from Kuleni (6557.3 kg ha^{-1}). The result illustrates that Gibe-1 had better yield performance under irrigation system. Melkamu and Molla (2016) also reported that Gibe-1 gave higher grain yield (7800 kg ha^{-1}) under the rain-fed system. However, the grain yield produced under irrigation was higher than that produced under rainfed. i.e the yield obtained under irrigation was by 39.5% greater than yield obtained under rainfed.

Table 7. Mean performance of six open pollinated maize varieties for yield and yield related traits in 2013/14 and 2014/15 off seasons

Variety	GY (Kg /ha)	PH (cm)	EH (cm)	DT	DS	EL	ED	CN ha^{-1}	EAS
Gibe-1	10883.4^{A}	253.2^{A}	158.5^{A}	105.7^{AB}	111.0^{B}	15.9^{BC}	5.5^{A}	47844^{BC}	1.83^{BC}
Gibe-2	8805.7^{B}	210.5^{C}	126.5^{B}	104.7^{B}	110.0^{BC}	14.6^{DC}	5.4^{A}	61226^{A}	1.75^{C}
Hora	6930.8^{C}	214.3^{C}	132.3^{B}	101.5^{B}	107.5^{C}	17.4^{A}	4.7^{C}	46550^{BC}	2.67^{A}
Guto	6660.7^{C}	214.8^{C}	127.4^{B}	109.5^{A}	115.2^{A}	14.0^{D}	4.9^{BC}	55817^{AB}	2.25^{AB}
Alemaya composite	8573.0^{B}	245.2^{AB}	156.2^{A}	104.2^{B}	110.0^{BC}	17.4^{A}	5.2^{AB}	38944^{C}	2.00^{BC}
Kuleni	6557.3^{C}	235.0^{B}	147.3^{A}	102.8^{B}	110.0^{BC}	16.9^{AB}	4.9^{BC}	38822^{C}	2.00^{BC}
CV (%)	14.2	5.3	7.9	3.5	2.2	7.9	5.5	17.85	19.1
R^2	0.86	0.86	0.77	0.61	0.71	0.89	0.75	0.75	0.74
LSD (0.05)	1369.1	14.4	13.3	4.3	2.9	1.5	0.33	10307	0.47
Year (Y)	*	***	***	*	NS	***	***	***	***
GxY	***	NS	NS	NS	*	*	NS	*	*

Where, G = Genotype, PH= Plant height, EH= Ear height, DT= Days to 50% tasseling, DS= Days to 50% silking, CN= Cob number, EAS= Ear aspect, ED = Ear Diameter, GY = Grain yield, EL = Ear Length

Conclusion and recommendation

Evaluation of the released improved maize varieties under irrigation to identify adapted varieties is an advantageous work as it helps to increase maize production to assure food security. Testing released improved maize varieties under irrigation is also a key indicator for the development of new maize varieties for irrigation production. Improved maize varieties showed high genetic variation for most traits revealing the importance of variety development for irrigation system. Hybrid variety, Shone had the highest grain yield (13458 kg ha^{-1}) performance followed by PHB3253 (Jabi) (13320 kg ha^{-1}) in 2013/14 with no significant difference. In 2014/15 irrigation season, hybrids BH-660 and AMH-760Q produced higher grain yield per hectare 10747 kg ha^{-1} and 10567 kg ha^{-1} respectively. Shone and AMH-760Q had good performance for grain yield combined over years 11486 kg and 11277 kg ha^{-1} in the same order. The mean grain yield potential of open pollinated maize varieties (OPVS) pointed out that Gibe-1 was out yielded in both years and combined over years. Gibe-1 gave 11673.8 kg ha^{-1} and 10093.1 kg ha^{-1} in 2013/14 and 2014/15 irrigation seasons respectively and the average grain yield performance was

10883.4 kg ha^{-1} combined over years. The result specified that the grain yield performance of most of the tested improved maize varieties was much higher than their rain-fed performance. Shone and Gibe-1 gave 35.1% and 39.5% yield increment respectively under irrigation compared to the rain-fed. Therefore, Shone and Gibe-1 are recommended as potential improved maize varieties for production under irrigation for grain yield for Koga irrigation scheme and areas with similar environments. AMH-760Q is also recommended as potential quality protein hybrid for production under irrigation for grain yield for Koga irrigation scheme and areas with similar environments.

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Evaluation of intercropping for the management of onion thrips (*Thrips tabaci*) at Ribb and Koga irrigation schemes in Western Amhara, Ethiopia

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Abstract:

Field experiments were conducted in 2013/14 and 2014/15 cropping seasons to evaluate different spatial arrangement of intercrops such as carrot (*Daucus carota*) and snap bean (*Phaseolus vulgaris*) with onion for the management of onion thrips (*Thrips tabaci*) on onion. Thrips damage incidence was determined in percentages and severity estimated on a scale of 1-5. Unmarketable and marketable bulb yield was determined at physiological maturity. All agronomic managements were equally applied to all plots and data were collected and subjected to analysis of variance using SAS statistical software and significant treatment mean differences were separated by using least significance difference at 5% significance level. All spatial arrangements of intercropping onion with snap bean and carrot significantly ($p \leq 0.05$) reduced thrips population by up to 54% at Koga and 76% at Rib; consequently the two intercrops did significantly ($p \leq 0.05$) reduced thrips damage severity at both locations. Intercropping onion with carrot and snap bean significantly ($p \leq 0.05$) increased marketable onion bulb yield at Koga and Rib, whereas the effect of these intercrops on unmarketable yield didn't show significant ($p > 0.05$) difference at Rib. Hence a 1:2 spatial arrangements of onions with snap bean and 1:3 of onion and carrot can be utilized in the management of onion thrips.

Keywords: Damage levels, Population, Spatial arrangement, Thrips

INTRODUCTION

Onion (*Allium cepa* L.) is one of an important vegetable produced across a wide range of latitudes in Africa, Asia, Europe and North America (Rabinowitch and Currah 2002). In Ethiopia, small-scale farmers grow onions and supply to the domestic market (CSA 2013).

Consumption of onions has been increasing significantly in the world partly because of the health benefits onions possess (Havey et al. 2004, Wang et al. 2006). Onions are also rich in flavonoids and alkenyl cysteine sulphoxides which play a part in preventing heart disease and other ailments in humans (Gareth et al. 2002, Havey et al. 2004, Javadzadeh A., et al. 2009).

Major factors limiting onion production are diseases and insect pests (Rabinowitch and Currah 2002, Muendo and Tschirley 2004). Onion thrips (*Thrips tabaci*) which is considered to be the most economically important pest of onion worldwide (Trdan et al. 2005) is responsible for causing considerable reduction in yield (Brewster 1994, Nawrocka 2003, Trdan et al. 2005). In Ethiopia, thrips are present in all onion growing areas and can cause up to 37% loss in yield (Waiganjo et al. 2008). Previous studies (Abate, 1986) showed that thrips numbers were highest in the hotter parts of the year (February through April), and lowest in the rainy seasons (June through August). Yeshitila Merene (2005) studied the population fluctuation of the onion thrips in 2004 in the northeastern part of the Amhara region, and reported a similar result. The population density of thrips was low during the rainy and cooler months of August to November and high during the months of February to April.

Currently, growers manage thrips by applying insecticides several times in a growing season. However, most insecticides are ineffective because a large number of thrips are always protected between the inner leaves of the onion plant and the pupal stage is hidden in the soil. In addition, *Thrips tabaci* is a very prolific species with many overlapping generations (Nault and Shelton 2010, Alimousavi et al. 2007, Shelton et al. 2006). It was reported that the efficacy of insecticides to control thrips was declining through time (Tsedeke Abate, 1983; Tsedeke Abate and Gashawbeza Ayalew, 1994; Gashawbeza Ayalew, 2005).

Development of resistance by onion thrips to most commonly used insecticides has been reported (Martin et al. 2003). Besides increasing the cost of production, the use of pesticides has negative effects on the environment and human health which is attributed to high chemical residues (Burkett-Cadena et al. 2008). Therefore, there is need to integrate the use of chemicals with other methods of control such as cultural practices (Dejene 2006) and use of resistant varieties in the management of thrips and other pests of onion. One sustainable method of managing pests is intercropping (Trdan et al. 2006, Finckh and Karpenstein-Machan 2002), a system in which a plant species (the intercrop) is grown specifically to reduce pest damage on a main crop. Intercropping is an important cultural practice that has been utilized in the management of weeds, insect pests and diseases in many crops worldwide (Trdan et al. 2006, Finckh and Karpenstein-Machan 2002). It is traditionally practiced by subsistence farmers in developing countries as a crop production system (Sodiya et al. 2010). The system is characterized by minimal use of pesticides and increases land productivity (Ullah et al. 2007). However, there are limited studies done in Ethiopia on management of thrips in onions using different spatial arrangement of intercrops. This study was therefore undertaken to evaluate the effectiveness of different spatial arrangements of intercrops for the management of thrips in onions fields.

MATERIALS AND METHODS

Experimental Design and Layout

Field experiments were carried out under irrigation conditions (November to April) at Koga and Rib irrigation schemes for two warm growing seasons 2013/14 and 2014/15. Treatments consisted of three different spatial arrangements (1:1, 1:2 and 1:3) of intercrops carrot *(Daucus carota*) and snap beans *(Phaseolus vulgaris*). Controls consisted of pure stands of onion variety Bombay red.

The experiment was laid out in a randomized complete block design (RCBD) with three replications. Plot size was 5 m * 6 m; spacing between plots was 1 m and between blocks was 1.5 m. On each plot where intercropping was done, one row of onion was alternated with one to three rows of intercrop with a spacing of 30 cm * 10 cm for onion, 45 cm * 10 cm for carrot, 45 cm * 20 cm for snap bean.

Assessment of Thrips Population and Damage

Assessment of thrips population was done by random destructive sampling of 5 plants per plot from the border rows of each plot. Silvery patches characteristically caused by thrips on onion leaves were used to assess thrips damage starting from the fourth week after transplanting to physiological maturity of the crop (four times). Incidence of thrips damage was determined by counting the number of damaged plants over the total number of plants per one row segment on three central rows per plot. Thrips damage severity was determined by randomly sampling ten plants from the inner rows of each plot. The percentage of leaf surface showing thrips damage was assessed based on a scale of 1 - 5 (Smith et al. 1994) where 1 = no damage, 2 = up to 25%, 3

= 26-50%, 4 = 51-75% and 5 = >75% damage. Leaf width (mm) were measured at full growth stages of the crop, whereas plant height (cm) was measured two times at vegetative and harvest stage, by taking samples from the inner rows.

Assessment of Bulb Yield

Harvesting was done by hand at physiological maturity when 50-80% of the foliage had fallen over and the tops and roots were cut off. The bulbs from each plot were weighed and marketable bulbs that were greater than 3 cm diameter separated and graded. Bulb length and diameter (mm) were measured at harvest time. The bulb yield for each spatial arrangements of intercrop treatment was converted into quintal per hectare.

Data Analysis

Data was checked for its distribution before statistical analysis. Analysis of variance (ANOVA) was performed using SAS 9.1.3 software package. Treatment means were separated using the Fisher's protected LSD test at 5% probability level. Regression analysis was made to find the relations of thrips population with yield and other associated parameters using SAS and the Minitab 14.

RESULTS AND DISCUSSION

Thrips Population

All intercropping with their respective spatial arrangements' significantly ($p \leq 0.01$) reduced thrips population at both locations Koga and Rib (Table 1). At Koga, the minimum thrips population of about 45% was observed on carrots (ratio 1:3) and about 44% on snap beans (ratio 1:1). At Rib, it was 44% and 56%, respectively (Table 1), the trend was similar at both locations. Previous reports suggest similar trends (Alamu et al. 2002). Intercrops reduce population of pests, preserve beneficial insects, reduce labor costs, control weeds and stabilize yields. Otherwise when temperatures are high, *Thrips tabaci* is a very prolific species with overlapping generations per season (Bergant et al. 2005; Alimousavi et al. 2007).

Table 1. Effect of spatial arrangements' of intercrops on mean number of thrips per sampled plants and their associated damages (%)

Spatial arrangements'	Thrips population		Incidence (%)		Severity	
	Koga	Rib	Koga	Rib	Koga	Rib
1 : 1/Onion : Carrot/	48.70^{c}	55.67^{bc}	20.07^{B}	4.67^{b}	3.67^{b}	3.67^{b}
1 : 2/ Onion : Carrot /	45.27^{c}	57.93^{bc}	35.42^{B}	7.33^{b}	3.00^{c}	2.67^{cd}
1 : 3/ Onion : Carrot /	44.80^{c}	43.73^{c}	22.43^{B}	5.33^{b}	2.00^{d}	2.00^{d}
1 : 1/Onion : Snap bean/	43.77^{c}	56.40^{bc}	23.61^{B}	6.00^{b}	3.33^{bc}	3.00^{bc}
1 : 2/Onion : Snap bean/	67.27^{b}	69.20^{b}	16.53^{B}	6.33^{b}	3.00^{c}	2.67^{cd}
1 ; 3 /Onion : Snap bean/	56.07^{bc}	59.53^{b}	20.07^{B}	5.33^{b}	2.00^{d}	2.00^{d}
Sole onion	88.40^{a}	126.13^{a}	63.75^{A}	18.67^{a}	5.00^{a}	5.00^{a}
CV (%)	17.60	19.79	38.12	37.85	9.40	12.59
Significance	***	***	**	***	***	**

*Where: *** = showed highly significant difference, values with the same letter showed no significant differences at P=0.05*

Relatively high temperatures and lack of rainfall have been associated with increase in onion thrips population, while high relative humidity and rainfall reduce thrips population (Hamdy and Salem, 1994). However, this study showed that intercropping onion with snap bean and carrot significantly reduced thrips population. Maximum (63.46 and 58.75 %) protection were recorded on 1:3 spatial arrangements' of carrots at Koga and Rib respectively (Table 2).

Table 2. The relative efficacy (%) of spatial arrangements of intercrops on the reduction of thrips population

Spatial arrangements of intercropping	Locations	
	Koga	Rib
1 : 1/Onion : Carrot/	49.07	22.93
1 : 2/ Onion : Carrot /	50.67	36.54
1 : 3/ Onion : Carrot /	63.46	58.75
1 : 1/Onion : Snap bean/	54.07	21.69
1 : 2/Onion : Snap bean/	51.24	34.40
1 : 3 /Onion : Snap bean/	76.13	54.86
Sole onion	-	-

This could have been due to visual and physical interference of thrips by the intercrops. Physical interference could cause attraction of thrips to intercrops instead of onions thereby resulting in reduction of their population on onions (Alston and Drost 2008, Trdan et al. 2006). Carrot foliage hide the onions from thrips view (Uvah and Coaker, 1984). Thrips injury to intercrops is not as economically damaging as injury to onions (Alston and Drost 2008). The reduction could also be attributed to reduced food concentration in a mixed ecosystem with non-host plants thereby reducing the rate of multiplication of thrips. Ramert and Lennartson (2002) reported that insects are attracted to and concentrated on their food plant resources which are more apparent in a simple monoculture system.

Damage Variables

Incidence: Silvery patches on experimental plants were considered as damage symptoms of thrips. All intercropping arrangements significantly ($p \leq 0.01$) reduced thrips damage incidence at both locations; the sole grown onion gave the highest damage incidence of about 18%. This may be associated with the thrips population per plant during the growing stage of the crop (Table 1).

Severity: Similarly, intercropped plots had significantly lower thrips damage severity (Table 1). At both locations, the highest mean severity of 5% was recorded on sole grown plants. The significant differences in thrips damage severity among the treatments indicates that the level of the ratio of the spatial arrangements of intercrops with onions and its influences on thrips population. Muthomi J.W. et al., (2012) reported that the three vegetable (Carrot, French bean and Spider plant) intercrops significantly ($p \leq 0.05$) reduced thrips damage severity, with spider plant having the greatest reduction of up to 15.7%.

Plant Growth and Development

Plant height: At Koga, plant height was significantly varied between treatments at harvest, but not at the vegetative stage. A minimum height (45.47 cm) was recorded on plots that received no intercrops. However there was no significant difference obtained between spatial arrangements' of intercrops (Carrot and Snap bean) except a 1:3 /Onion: Snap bean/ at harvest stage at Koga irrigation scheme. At Rib, it was significant regardless of plant growth stage, however a minimum heights (38.83, 42.63 cm') were recorded on sole planted onions than the intercropped followed by a 1:1/Onion: Carrot/ which was (46.03, 51.80 cm'), maximum height (53.47, 62.23 cm') were recorded on plots that received a 1: 3 /Onion: Snap bean/ spatial arrangements' of intercrops at vegetative and harvest respectively (Table 3).

Table 3. Effect of spatial arrangements' of intercrops on plant height (cm) of onions

Spatial arrangements'	Vegetative stage		Harvest stage	
	Koga	Rib	Koga	Rib
1 : 1/Onion : Carrot/	43.80	46.03^{bc}	52.93^{a}	51.80^{b}
1 : 2/ Onion : Carrot /	38.93	46.27^{ab}	51.80^{a}	55.87^{ab}
1 : 3/ Onion : Carrot /	42.60	51.00^{ab}	52.53^{a}	56.00^{ab}
1 : 1/Onion : Snap bean/	43.33	48.33^{ab}	53.20^{a}	55.47^{ab}
1 : 2/Onion : Snap bean/	40.60	48.47^{ab}	52.47^{a}	54.93^{ab}
1 : 3 /Onion : Snap bean/	38.87	53.47^{a}	49.47^{ab}	62.23^{a}
Sole onion	32.00	38.83^{c}	45.47^{b}	42.63^{c}
CV (%)	11.22	8.65	5.11	9.41
Significance	NS	*	*	*

*Where: values with the same letter showed no significant differences at P=0.05, NS = stands for non- significance * = stands for significant*

Yield and Yield Components

Bulb size: Generally, onions grown in intercrops had higher bulb length and bulb diameter than sole grown onions at both locations (Table 4). At Koga, bulb length was statistically the same in all intercrop combinations. However at Rib, plots intercropped with carrots had less bulb length. Bulb diameter was more or less the same in all intercrop combinations at Koga. However at Rib, 1:3 ratio of carrots and snap beans had significantly higher bulb diameter.

As Haider Karar *et.al*.,(2014) reported, maximum population 160.2/ plant, bulb weight 27.0 g and bulb diameter 7.0 mm were recorded from unprotected plots. Whereas, in case of protected plots the population remained 12.2 /plant, bulb weight 40.9 g and bulb diameter was 13.8 mm.

Table 4. Effect of spatial arrangements' of intercrops on the bulb sizes of onions

Spatial arrangements'	Bulb lengths(mm)		Bulb diameter (mm)	
	Koga	Rib	Koga	Rib
1 : 1/Onion : Carrot/	53.00^{ab}	52.40^{c}	33.17^{ab}	53.73^{b}
1 : 2/ Onion : Carrot /	58.80^{a}	54.20^{bc}	33.19^{ab}	56.80^{b}
1 : 3/ Onion : Carrot /	56.93^{a}	59.43^{a}	34.41^{a}	61.70^{a}
1 : 1/Onion : Snap bean/	56.20^{a}	57.73^{ab}	33.87^{a}	49.60^{c}
1 : 2/Onion : Snap bean/	58.13^{a}	56.67^{abc}	33.32^{ab}	56.47^{b}
1 ; 3 /Onion : Snap bean/	53.00^{ab}	54.60^{abc}	31.24^{bc}	61.53^{a}
Sole onion	48.80^{b}	40.77^{d}	30.67^{c}	45.63^{d}
CV (%)	6.23	5.32	3.98	3.84
Significance	*	***	*	***

*Where: values with the same letter showed no significant differences at P=0.05, * = stands for significant & *** = stands for highly significant*

Bulb yield: At Koga, plots intercropped with 1:2 of snap bean and 1:3 carrot gave significantly higher marketable yield than sole grown onions (Table 5). Other combinations did not vary significantly. At Rib, 1:3 ratios of both intercrops had significantly higher marketable yield than the sole plants. Unmarketable yield did not show some discernible pattern but it generally tended to be high on sole grown onions than on intercropped onions.

Table 5. Effect of spatial arrangements' of intercrops on marketable and un-marketable yield (qt/ha) of onions

Spatial arrangements'	Marketable yield		Un marketable yield	
	Koga	Rib	Koga	Rib
1 : 1/Onion : Carrot/	144.57^{bc}	112.67^{d}	6.00^{b}	0.00 (0.71)
1 : 2/ Onion : Carrot /	145.23^{bc}	152.43^{c}	9.23^{a}	0.33 (0.57)
1 : 3/ Onion : Carrot /	171.67^{ab}	233.77^{a}	7.90^{ab}	0.33 (0.57)
1 : 1/Onion : Snap bean/	134.67^{bc}	99.10^{d}	8.10^{ab}	0.00 (0.71)
1 : 2/Onion : Snap bean/	207.23^{a}	184.23^{b}	7.90^{ab}	0.10 (0.32)
1 ; 3 /Onion : Snap bean/	147.57^{bc}	236.10^{a}	7.10^{b}	0.43 (0.66)
Sole onion	122.23^{c}	114.00^{d}	10.90^{a}	0.10 (0.32)
CV (%)	17.87	8.59	20.48	8.79
Significance	*	***	*	NS

*Where: values with the same letter do not show significant differences; NS = stands for non- significance, numbers in the parenthesis are transformed values of the corresponding number, * = stands for significant & *** = stands for highly significant*

Correlations analysis

The unmarketable yield was significantly positively correlated with thrips population whereas bulb diameter and lengths was significantly but negatively correlated with unmarketable yield. Although not significant the damage percentages showed positive correlations with thrips population; however bulb length and bulb diameter showed highly significant negative correlations with thrips population (Table 6).

Table 6. Correlations between various dependent variables recorded during the growth period

	UMY	MY	DS	BD	BL	DP	NT
Un-marketable yield (UMY)	1.000	-0.222 NS	0.134 NS	-0.452 *	-0.016 *	0.115 NS	0.452 *
Marketable yield (MY)		1.000	0.045 NS	0.304 NS	0.301 NS	-0.488 *	-0.031 NS
Damage (DS)			1.000	-0.215 NS	-0.268 NS	0.241 NS	0.308 NS
Bulb diameter (BD)				1.000	0.643 ***	-0.113 NS	-0.712 ***
Bulb length (BL)					1.000	-0.246 NS	-0.558 ***
Damage percentage (DP)						1.000	0.199 NS
Number of thrips (NT)							1.000

** = stands for significant, *** = stands for highly significant, NS = stands for not significant.*

Regression Analysis

The regression analysis was done between different yield and yield related parameters'. Bulb length was regressed with thrips population and showed that as thrips population increases the bulb length decreases with the regression equation (BL=222-3.01TP), however the coefficient of determination (R^2) is low (R^2=42.4%) (Figure 1).

The thrips population were also regressed with bulb diameter and plant heights and showed that as the thrips population increases the bulb diameter and plant heights decreased with its respective regression equation and coefficient of determinations (Figures 2, 3 & 4).

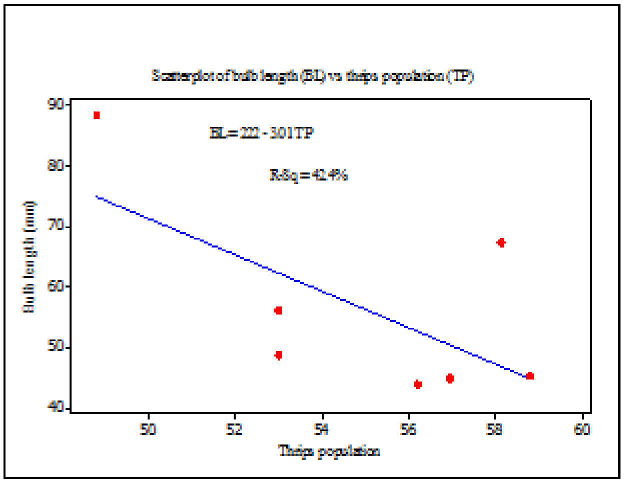

Figure 1. Regressions between bulb length (BL) vs thrips population (NT) at Koga

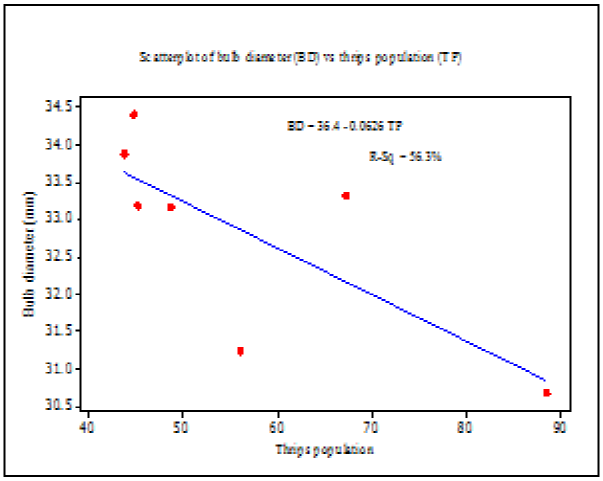

Figure 2. Regressions between bulb diameter(BD) vs thrips population (TP) at Koga

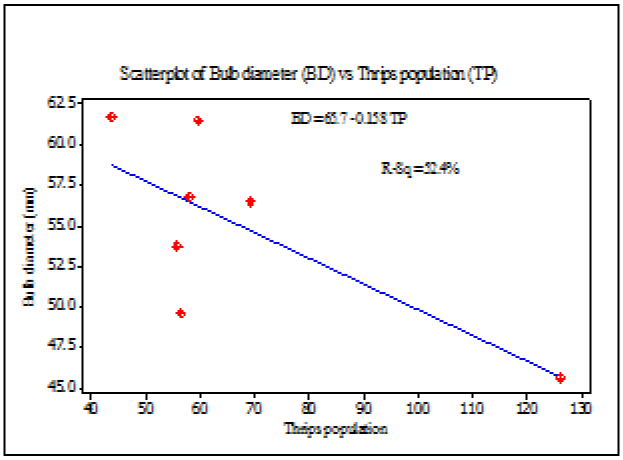

Figure 3. Regressions between bulb diameter(BD) vs thrips population (TP) at Rib

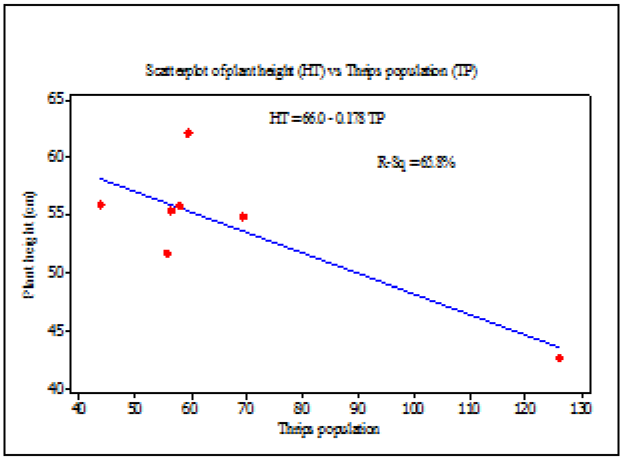

Figure 4. Regressions between plant height (HT) vs thrips population (TP) at Rib

Intercropping of onions with spider plant and carrots reduce onion bulb yields (Trdan et al. 2006, Kabura et al. 2008); however our intercropping was not affecting the recommended spacing's to the main crop (Onion). This study showed that thrips population and damage on onion can be significantly reduced when the inter crops are spatially arranged to 1:2/onion: carrots/ and 1:3 /onion with snap bean/.

Intercrops offer an alternative to the use of chemicals thereby reducing the development of resistance that has been reported in many of the currently registered insecticides (Shelton et al. 2006, Nault and Shelton 2010, Diaz-Montano et al. 2011). Intercrops not only reduce pest populations but they also preserve beneficial insects, reduce labor costs incurred in application of pesticides, control weeds and stabilize yields (Alamu et al. 2002).

CONCLUSIONS

The direct and indirect damage on onions by thrips was reflected by the plant height, leaf width, bulb sizes, etc. Damage levels varied because of different spatial arrangements of intercrops (carrots and snap beans) with onions. The significant reduction in thrips population and damage in the onion-carrot and onion-snap bean intercrops with their spatial arrangements (1: 2 and 1:3) showed that this arrangement can be utilized for the integrated management of this economically important pest of onion and can be taken as an alternative to insecticides for small holder farmer.

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