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Influences of inter and intra row spacing on yield, yield component and morphological characteristics of onion (*Allium cepa* L.) at Western Amhara region

Habtamu Tegen[1]*, Minuyelet Jembere[1], Esmelealem Mihiretu[1] and Alebachew Enyew[2]

[1]Directorate of Crop Research, Adet Agricultural Research Center, P. O. Box 08, Bahir Dar, Ethiopia.
[2]Directorate of Soil and Water Research, Adet Agricultural Research Center, P. O. Box 08, Bahir Dar, Ethiopia.

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Appropriate spacing enables the farmers to keep appropriate plant population in the field. Hence, it can avoid over or less population in a given plot of land which has negative effect on yield and quality of onion. Spacing of 40 × 20 × 10 cm between furrow, row and plants, respectively has been used for onion production in Ethiopia. But producers complain 10 cm intra row spacing produces large bulb size which is not preferred by consumer for home consumption. To optimize onion productivity, full package of information is required. To fill this gap field experiment was conducted to study the effect of inter and intra row spacing on the bulb yield and yield components of onion at Ribb in Fogera, Woramit in Bahir Dar and Koga in Mecha districts in 2014. The interaction of the lowest inter and intra row spacing mature earlier by 15 days compared to highest inter and intra row spacing. Forty nine percent of medium sized bulbs were produced with the interaction of 15 and 6 cm inter and intra row spacing while only 32% of medium sized bulbs were produced by the interaction of 25 and 8 cm inter and intra row spacing. Small sized bulb distribution decreased as intra row spacing increased while large bulb sized distribution increased when intra row spacing increased. The highest bulb weight (102 g) was produced by the interaction of highest inter and intra row spacing while the lowest bulb weight (45 g) was produced by the lowest inter and intra row spacing. Interaction of inter and intra row spacing of 15 and 4 cm respectively, scored the 1st highest marketable bulb yield (39 ton ha^{-1}) and interaction of 15 and 6 cm inter and intra row spacing scored the 2nd highest marketable bulb yield (36 ton ha^{-1}). The result revealed that the earlier recommendation (20 and 10 cm inter and intra row spacing) produced more number of medium and large sized bulbs with a yield penalty of 8.0 and 10 ton per ha^{-1} compared to interaction of inter row spacing of 15 cm with intra row spacing of 6 and 4 cm, respectively. Therefore, the interaction of inter and intra row spacing of 15 with 6 cm is recommended as a first option for producers who wishes to produce maximum bulb yield with maximum medium sized bulbs. It is also confirmed that earlier recommendation is better as a second option for producers who wishes to produce for export market which requires medium and large sized bulbs of onion.

Key words: Onion, inter, intra, spacing, bulb, yield.

INTRODUCTION

Among the common irrigated vegetables, onion (*Allium cepa* L.) ranks number one both in area coverage and local consumption in Ethiopia. In 2012, the total production of onion in Ethiopia was about 3,281,574 tons from 30,478 ha of land with average yield of 10.76 ton per ha^{-1} (FAO, 2012). Particularly, it is the popular vegetable grown under irrigation in most of the traditional and the recent modern irrigation schemes in Ethiopia. However, the largest production of onion is not supported with improved production practices like spacing to improve its productivity and bulb quality. To avoid nutrient competition sufficient spacing between plants and rows is vital to get maximum yield in given land. Appropriate spacing enables the farmer to keep appropriate plant population avoid over and less population in a given plot of land which has negative effect on yield and quality (EARO, 2004). Seedlings are widely transplanted with the spacing of 40 × 20 × 10 cm between furrow, row and plants, respectively in Ethiopia. Recently research results confirmed that spacing of 10 cm between plants produced large bulb size. On the other hand individual consumers do not prefer these large sized bulbs for home consumption (EHDA, 2011). For example, Geremew et al. (2010) recommended intra row spacing of 4 cm for 'Nasik' Red and 'Adama' Red varieties, and 6 cm for 'Bombay' Red variety, in central rift valley areas of Ethiopia. Whereas, according to Tadesse (2008), onion farmers in Fogera area do not keep the recommended spacing. They do not use any measurement to keep the spacing. Because of this there is no specific distance between both rows and plants. According to Yemane et al. (2013) finding the largest bulb size was produced by the larger intra-row spacing (10 cm), showed highest rotting percentage compared to intra-row spacing (5 and 7.5 cm). Bosekeng (2012) also observed that large plants grown at wider spacing are associated with split bulbs and sensitive to a cold stimulus causing bolting. To optimize onion productivity, full package of information is required (Lemma and Shimeles, 2003). Plant population needs to be optimized. The optimum use of spacing or plant population has dual advantages. It avoids strong competition between plants for growth factors such as water, nutrient and light. In addition optimum plant population enables efficient use of available cropland without wastage (Geremew et al., 2010).

The average productivity of onion in Amhara region was 13.76 t ha^{-1} which was very low as compared to other onion producing countries (CSA, 2012). This is attributed to shortage of improved technologies, limited awareness on the production practice that affect to exploit the full potential benefits of the crop. There is also lack of location specific researches on onion in particular and for other crops in general. In addition, the quality of the produce is also inferior due to pre-harvest and post-harvest biotic and abiotic factors. Therefore, in view of those gaps on onion production and productivity, the study was conducted to evaluate the influence of inter and intra row spacing on bulb yield and physical bulb quality of onion under western Amhara conditions.

MATERIALS AND METHODS

Description of the study areas

Woramit

Woramit is located in North-western part of Bahir Dar town on the shore of Lake Tana in Ethiopia. It is located at 11°38′ N and 37°10′ E which is about 563 km North of the capital city, Addis Ababa. The area has an altitude of 1800 m above sea level. It has warm and humid climate with distinct dry and wet seasons. The mean daily maximum temperature is 29.5°C in April. The mean daily minimum temperature is 6.2°C in January. The area receives a mean annual rainfall of 800 to 1250 mm. The area is characterized as mild altitude agro-ecology. The soil at the Woramit experimental site is Nitosol. The soil is moderately acidic (pH 6.4) with soil texture of sand (13%), silt (33%) and clay (54%). It has very low organic matter content (3.9 %). Available phosphorus content is low (6.3 mg/kg). It has medium total nitrogen contents (0.16%).

Koga

Koga is located in the North West part of Ethiopia in Mecha woreda. It is located between 11° 10' and 11° 25' North latitude and 37° 2' and 37° 17' East longitude in Blue Nile basin, which is about 540 km North of the capital city, Addis Ababa. The mean annual rainfall recorded at Merawi station is 1480 mm, of which 90% falls in the months May to October. The monthly mean temperature is 25.8°C. The elevation is 1960 m above sea level, and the slope ranges from nearly flat to 5%. The area is characterized as mild altitude agro-ecology. The soil at the Koga experimental site is Nitosol. The soil is strongly acidic (pH 5.1-5.3) with high exchangeable acidity (1.54-5.23) and high exchangeable Al^{3+} (0.92-2.88 cmol kg^{-1}) content. It has very low organic matter content (2.34-4.44%). Available phosphorus content is low (3.54-8.69 ppm). It has medium total nitrogen contents (0.18-0.24%).

Ribb

Ribb is located in North West part of Ethiopia in Fogera woreda. It is located at 11°44' to 12° 03' North and 37°25' to 37°58' East which is about 605 km North of the capital city, Addis Ababa. Its altitude is 1774 m above sea level. It receives 1400 mm mean annual rain fall. The mean daily maximum temperature is 30°C. The mean daily minimum temperature is 11.5°C. The area is characterized as mild altitude agro-ecology. The soil at the Ribb experimental site is fluvisol (an alluvial deposit). The soil has high available phosphorus (36.71 ppm) and very low to low total nitrogen contents (0.003). The CEC is high (33.00 cmol kg^{-1}). The soil is strongly acidic with high exchangeable acidity and high exchangeable Al^{3+} content. It has very low organic matter content. Available phosphorus content is low.

*Corresponding author. E-mail: habitt2006@yahoo.com.

Experimental materials, treatments and experimental design

Onion variety used for the study was 'Bombay red'. The experiment consists of three inter row spacing (15, 20 and 25 cm) and four intra row spacing (4, 6, 8, 10 cm) which was arranged in 3 × 4 factorial combination in Randomized Complete Block Design with three replications.

Experimental procedure

When seedlings reached at appropriate stage for transplanting, it was transplanted on 6 m^2 gross plot size (3 × 2 m). Four, three and two central double rows were maintained for the inter row spacing of 15, 20 and 25 cm, respectively. 25, 30 and 40 cm furrow width were also maintained for the inter row spacing of 15, 20 and 25 cm, respectively for irrigation water application (Figure 1). Based on the recommendation of each testing sites, 100 and 285 kg DAP and Urea ha^{-1} for Ribb, 300 and 100 kg DAP and Urea per ha^{-1} for Koga and 200 and 100 DAP and Urea ha^{-1} for Woramit was applied. The whole rate of DAP was applied at the time of transplanting while Urea was applied in two splits, half at the time of transplanting and half at 45 days after transplanting. 0.75 litter per hectare base of Selecron® 720 EC, was applied every two weeks interval for the control of onion trips. Other agronomic management practices were applied according to the national recommendation.

Data collection

Morpho-phenological traits

Days to maturity (DM): The actual number of days from seedling transplanting to the field to a day at which more than 90% of the plants in a plot showing yellowing of leaves was recorded to determine the days to physiological maturity.

Plant height (PH) (cm): The mean height of ten randomly selected plants was measured and divided by number of plant taken. It was measured using ruler from the soil surface to the tip of the leaves at bulb development stage.

Leaf number per plant (LN): The mean number of leaves produced by ten randomly selected plants. It was recorded at bulb development stage and expressed as number of leaves per plant.

Yield components

Bulb diameter (BD) (cm): The mean bulb diameter of ten randomly selected plants. It was measured by using caliper at the widest point in the middle portion of the matured bulb and expressed in cm.

Average bulb weight (ABW) (g): Average fresh weight of ten randomly selected marketable bulbs was measured by using digital balance from central rows of each plot and expressed in gram.

Bulb size distribution (%): Two holes with different size (65 cm and 45 cm diameter) were prepared on thick carton paper sheet. Bulbs which were not passed through 65 cm hole were considered as big bulbs, bulbs which were passed through 65cm hole but not passed through 45 cm hole were considered as medium bulbs and bulbs which were passed through 45 cm hole were considered as small bulbs. Numbers of different sized bulbs were converted in percent by the following formula.

$$\% = \frac{number\ of\ different\ sized\ bulbs}{Total\ bulbs} x\ 100$$

Bulb yield

Marketable bulb yield (MBY) (t ha^{-1}): Total weight of clean, disease and damage free bulbs were measured per net plot and converted to tha^{-1}.

Unmarketable bulb yield (UMBY) (t ha^{-1}): Total weight of under sized bulb,
decay, physiological disorder such as thick necked, split and bolters were measured per net plot and converted to t ha^{-1}.

Total bulb yield (TBY) (t ha^{-1}): Total weight of marketable and unmarketable bulbs were measured per net plot and converted to t ha^{-1}.

Statistical analysis

Analysis of variance (ANOVA) was computed using SAS (9.00 version) software. Duncan multiple range tests at 5% probability level was carried out for mean separation. Excel micro soft program was used to draw graphs.

RESULTS AND DISCUSSION

Morpho-phenological traits

The analysis of variance result revealed that all morpho-phenological attributes including plant height, number of leaves per plant and days to 90% plant maturity was significantly (P<0.05) influenced by location. The significant location effect (P<0.05) demonstrates that there were location difference in terms of weather conditions, soil physical and chemical properties which determines the general growth and yield of onion as it is described in site descriptions. Although the performance of onion growth and yield was differing from location to location, the overall effect of the treatments have similar trend from location to location. All these traits were also significantly (P<0.05) affected by both the main effect inter and intra row spacing. With the same manner inter row, intra row spacing and location interaction significantly (P<0.05) influenced all morpho-phenological attributes tested. All possible two way interactions (inter x intra, inter × location and intra × location) significantly (P<0.05) influenced plant height and 90% plant maturity except leaf number per plant (Table 1).

Plants grown with the combination of the highest inter row spacing of 25 cm and the highest intra row spacing of 10 cm recorded the highest value (51.42 cm) for plant height. On the other hand plants grown with the combination of the lowest inter row spacing of 15 cm and lowest intra row spacing of 4 cm recorded the lowest plant height value (45.35 cm). It is justified by Khan et al. (2002) that due to high

Table 1. Mean squares from analysis of variance (ANOVA) for growth physical quality and yield and yield related traits of onion.

Source of variation	df	Mean squares										
		DM	PH	BD	LN	Bulb size distribution			BW	MBY	UMBY	TBY
						Small (%)	Medium (%)	Large (%)				
Inter row	2	516**	94**	1.55**	9.82*	4590**	188**	5187**	9215**	2784359051**	69365486**	3723845995**
Intra	3	278**	36**	1.31**	24.89**	2457**	314**	3268**	6570**	196651242**	64576751^{ns}	484727238 **
Rep	2	8^{ns}	0.48^{ns}	0.12^{ns}	1.09^{ns}	7.48^{ns}	4.88^{ns}	18^{ns}	128^{ns}	638791^{ns}	1190486^{ns}	1817297^{ns}
Loc	2	1027**	2237**	134.4**	165.40**	8272**	935**	9311**	8194**	2726418981**	68387708**	2828449051**
Inter*Intra	6	9*	14*	0.29*	0.65^{ns}	109**	116**	146**	556**	52342307*	4493881*	45070918*
Inter*loc	4	75**	85**	0.19^{ns}	3.90^{ns}	406**	323**	143**	61^{ns}	122323287**	13440486^{ns}	193860579**
Intra*loc	6	10*	9^{ns}	0.25*	0.59^{ns}	161**	726**	238**	175^{ns}	34059691^{ns}	4658696*	28413696^{ns}
Inter*intra*loc	12	175**	18**	0.09^{ns}	1.99^{ns}	74**	177**	159**	191^{ns}	37546590*	2512631^{ns}	36463627*
Error	70	3	5	0.11	2.87	21.74	29.28	24.99	114	19426618	1734295	18964542

*, ** and ns- significant (P<0.05), highly significant (P<0.01) and non significant, respectively. DM, Days to maturity, PH, plant height, BD, bulb diameter; LN, leaf number; BW, bulb weight; MBY, marketable bulb yield; UMBY, unmarketable bulb yield; TBY, total bulb yield.

competition among the closest plant spacing, onion produced least response for plant height. Plants grown with the combination of highest inter row spacing of 25 cm and highest intra row spacing of 10 cm took longer time (125 days) for maturity. On the other hand plants grown with the combination of the lowest inter row spacing of 15 cm and the lowest intra row spacing of 4 cm took shortest time 110 days for maturity. The combination of the lowest inter row spacing (15 cm) with lowest intra row spacing (4 cm) mature earlier by 15 days as compared to highest inter row spacing (25 cm) with highest intra row spacing (10 cm). The delay in maturity due to wider spacing could be possibly due to the fact that plants in wider intra-row spacing did not compete for resources (nutrients, sun light, water and space) so that they prolonged their vegetative stage. The current study identified the advantage of using closer spacing for early bulb yield to fetch maximum price from the early market.

Yield components

Bulb size distribution

The analysis of variance result revealed that bulb size distribution viz. small (<45 mm in diameter), medium (45-65 mm in diameter) and big (>65 mm in diameter) was significantly influenced by the main effect inter, intra and location. All these traits were also significantly affected by inter row, intra row spacing and location interaction. All possible two way interactions (inter × intra, inter × location and intra × location) influenced onion bulb size distribution (Table 1).

More than 50% of small sized bulbs was produced with the interaction effect of the lowest inter row spacing of 15 cm and lowest intra row spacing of 4 cm, while 16% of small bulbs were produced with the interaction effect of highest inter row spacing of 25 cm and highest intra row spacing of 10 cm. Forty nine percent of medium sized bulbs were produced with the interaction effect of 15 and 6 cm inter and intra row spacing, respectively while only 32% of medium sized bulbs were produced by the interaction effect of 25 and 8 cm inter and intra row spacing. Forty eight percent of large sized bulbs were produced by the interaction effect of highest inter row spacing of 25 cm and highest intra row spacing 10 cm while only 8% of large sized bulbs produced by the interaction effect of the lowest inter row spacing of 15 cm and lowest intra row spacing of 4 cm. The current result indicated that small sized bulb distribution decreased as intra spacing increased while large bulb sized distribution increased when intra row spacing increased (Figure 2). Consumer's preferences regarding to bulb size of onion, medium sized (45-65 mm) bulbs are most preferable for most household conditions. Large sized bulbs (>65 mm) are mostly preferred for hotel, restaurant and export market in Ethiopian conditions.

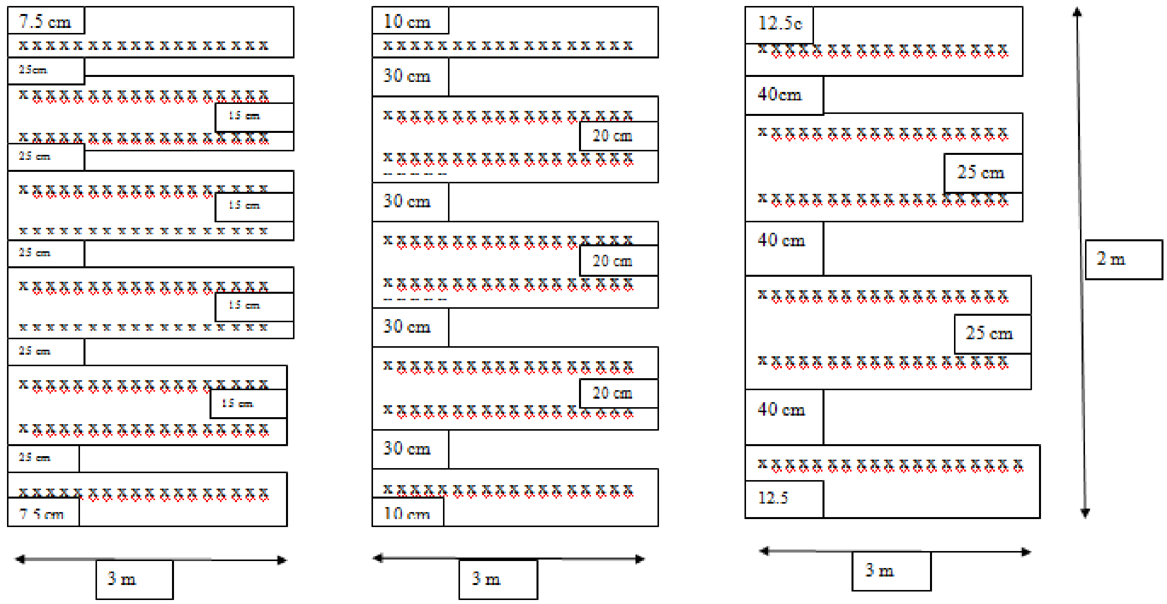

Figure 1. Spatial arrangements of rows, ridges and furrows on the plot for each inter row spacing treatment (15, 20 and 25 cm).

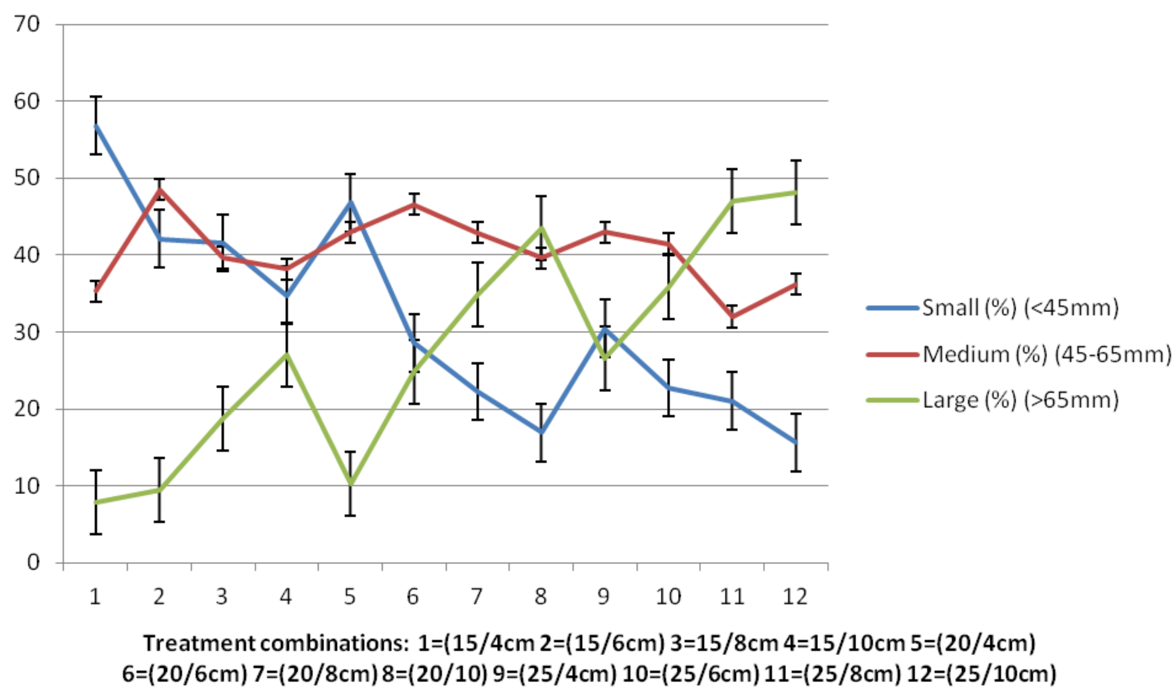

Figure 2. Bulb size distribution as affected by inter and intra row spacing of onion.

Average bulb weight (g)

The analysis of variance result revealed that bulb weight was significantly influenced by the main effect inter, intra and location. This traits was also significantly affected by the interaction of inter row and intra row spacing. All possible way interactions (inter × location, intra × location and inter × intra × location) was not statistically affected onion bulb weight except two way interaction inter and intra row spacing (Table 1). The highest bulb weight (102

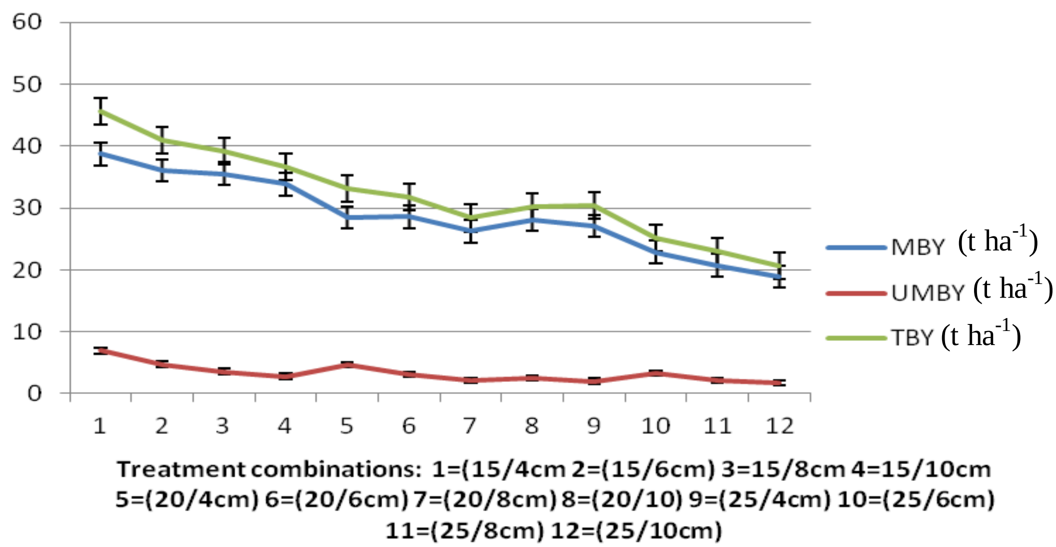

Figure 3. Onion bulb yield trend as affected by inter and intra row spacing of onion.

g) was produced by the interaction effect of highest inter row spacing of 25 cm with highest intra row spacing of 10 cm while the lowest bulb weight (45 g) was produced by the lowest inter row spacing of 15 cm with lowest intra row spacing of 4 cm. The increment in bulb weight due to increase in intra-row spacing might be due to the growth of taller plants with higher number of leaves causing higher synthesis and transportation of photosynthetic product from source to sinks and plants widely spaced experienced little or no competition for limited growth resources compared to closely spaced plants as described by Khan et al. (2002) and Biswas et al. (2003).

Average bulb diameter (mm)

The analysis of variance result revealed that bulb diameter was significantly influenced by the main effect inter, intra and location. This traits was also significantly affected both two way interaction of inter row by intra row spacing and intra by location. Two way interaction of inter by location and three way interaction of (inter × intra × location) was not statistically affected bulb diameter (Table 1). Significantly the first highest bulb diameter (7.12 mm) was produced by the interaction effect of 25 cm inter and 8 cm intra row spacing and the second highest bulb diameter (7.08 cm) was produced by the interaction of 20 cm inter row and 10 cm intra row spacing without statistically non-significant bulb diameter. On the other hand significantly lowest bulb diameter (6.20 cm) was produced when bulbs have been produced by the interaction effects of lowest inter row spacing of 15 cm and lowest intra row spacing of 4 cm. The present result was in line with that of Khan et al. (2002) who reported that wider intra-row spacing (12 cm) gave larger bulb diameter (5.13 cm) of onion. Whereas the closest(9 cm) spaced plants gave the lowest bulb diameter (3.80 cm). The increase in bulb diameter at wider spacing could be attributed to availability of more nutrients and moisture due to less competition effects in different physiological and metabolic processes through increase in dry matter production..

Onion bulb yield (t ha^{-1})

Marketable and total bulb yield per hectare

The analysis of variance result revealed that both marketable and total bulb yield was significantly influenced by the main effects inter, intra and location. Both traits were also significantly affected two way interaction of inter × intra and inter × location except intra × location. With the same manner inter row, intra row spacing and location interaction influenced both marketable and total bulb yields (Table 1). The interaction effect of the lowest inter row spacing of 15 cm with lowest intra row spacing of 4 cm scored the first highest marketable and total bulb yield of 39 and 46 t ha $^{-1}$, respectively. The interaction effect of the lowest inter row spacing of 15 cm with intra row spacing of 6 cm scored the second highest marketable and total bulb yield of 36 and 41 t ha $^{-1}$, respectively with statistically non-significant yield difference between the two treatment combinations. On the other hand interaction effect of highest inter row spacing of 25 cm with highest intra row spacing of 10 cm scored the lowest marketable and total bulb yield of 19 and 21 t ha^{-1}, respectively (Table 2). Generally, bulb yield increases significantly as population density increases (Figure 3). The current study indicated

Table 2. Interaction effect of inter and intra row spacing on bulb size distribution and yield of onion combined over locations.

Treat	DM	PH (cm)	BD (cm)	Bulb size distribution			BW	MBY	UMBY	TBY
				Small (%) (<45 mm)	Medium (%) (45-65 mm)	Large (%) (>65 mm)	(g)	(t ha^{-1})	(t ha^{-1})	(t ha^{-1})
15-4	110.66^{f}	45.35^{c}	6.20^{e}	56.78^{a}	35.29^{cd}	7.91^{g}	45.54^{d}	38.71^{a}	6.95^{a}	45.66^{a}
15-6	112.11^{f}	46.91^{bc}	6.35^{de}	42.09^{bc}	48.47^{a}	9.43^{g}	49.11^{cd}	36.1^{a}	4.75^{b}	40.92^{ab}
15-8	116.00^{e}	47.35^{bc}	6.58^{bcd}	41.60^{bc}	39.67^{bcd}	18.71^{f}	51.85^{cd}	35.55^{a}	3.57^{bc}	39.13^{b}
15-10	117.5^{de}	45.17^{c}	6.41^{cde}	34.79^{cd}	38.16^{bcd}	27.04^{de}	69.30^{b}	33.86^{ab}	2.8^{cd}	36.71^{bc}
20-4	116.11^{e}	47.5^{bc}	6.60^{bcd}	46.78^{b}	42.98^{abc}	10.23^{g}	47.55^{d}	28.45^{c}	4.68^{b}	33.13^{cd}
20-6	117.8^{de}	48.27^{abc}	6.64^{bcd}	28.59^{de}	46.59^{ab}	24.8^{ef}	73.64^{b}	28.60^{bc}	3.11^{bcd}	31.71^{cd}
20-8	119.33^{cd}	49.98^{ab}	6.81^{ab}	22.25^{ef}	42.92^{abc}	34.82^{cd}	72.03^{b}	26.22^{cd}	2.13^{cd}	28.362^{de}
20-10	123.88^{ab}	48.62^{abc}	6.75^{bc}	16.91^{f}	39.63^{bcd}	43.45^{ab}	99.73^{a}	28.08^{cd}	2.55^{cd}	30.13^{de}
25-4	116.88^{de}	46.17^{bc}	6.22^{e}	30.47^{d}	42.95^{abc}	26.57^{ef}	64.88^{bc}	27.12^{cd}	2.04^{cd}	30.48^{d}
25-6	121.66^{bc}	49.80^{ab}	6.67^{bcd}	22.72^{ef}	41.49^{abcd}	35.78^{bc}	79.17^{b}	22.88^{de}	3.35^{bcd}	25.22^{ef}
25-8	122.11^{bc}	49.75^{ab}	7.12^{a}	21.00^{f}	32.00^{d}	47.00^{a}	96.84^{a}	20.75^{e}	2.15^{cd}	22.91^{f}
25-10	125.11^{a}	51.42^{a}	7.08^{a}	15.65^{f}	36.18^{cd}	48.15^{a}	101.9^{a}	18.86^{e}	1.80^{d}	20.67^{f}
R^2	0.95	0.93	0.97	0.96	0.85	0.96	0.88	0.90	0.83	0.92
Sig.	**	**	*	**	**	**	**	*	*	*
CV%	1.54	5.03	5.05	14.85	13.31	17.88	15.09	12.30	31.91	10.89

Means in the column with the same letter are none statistically significant at (5%). DM, Days to maturity, PH, plant height, BD, bulb diameter; LN, leaf number; BW, bulb weight; MBY, marketable bulb yield; UMBY, unmarketable bulb yield; TBY, total bulb yield.

that beyond 15 and 6 cm inter and intra row spacing, the number of small sized bulbs per hectare increased with statistically non-significant bulb yield difference. Bleasdale (1966) and Frappell (1973) reported similar results by stating the total yield of ripe bulbs increased with increasing number of plants per square meter until an optimum was reached and thereafter the yield declined. Kantona et al. (2003) concluded that, planting densities significantly affected the onion bulb yield.

Unmarketable yield

The analysis of variance result revealed that unmarketable bulb yield was significantly influenced by the main effects inter, intra and location. This trait was also significantly affected by the two way interaction of inter × intra and intra × location except inter × location. Three way interaction of inter × intra × location was none statistically influenced unmarketable bulb yield (Table 1). The highest unmarketable bulb yield of 7 ton per ha^{-1} was obtained when onion was produced with lowest inter and intra row spacing 15 and 4 cm, respectively. Whereas, the lowest unmarketable bulb yield of 2 ton per ha^{-1} was obtained when onion was produced with the highest inter and intra row spacing of 25 and 10 cm, respectively. This is for the reason that close spacing resulted in high undersize bulb as the consequence of higher competition between plants. This finding was in agreement with similar study of Seck and Baldeh (2009) who concluded that plant density has an impact on unmarketable bulb size.

CONCLUSIONS AND RECOMMENDATIONS

Bulbs produced by the interaction effect of 15 cm inter with 4 and 6 cm intra row spacing of mature earlier by 15 and 13 days compared with wider inter and intra row spacing of 25 and 10 cm, respectively. Producing two weeks early bulb yield by using closer spacing may play a significant role for producers to fetch maximum price from the early market. Maximum percent of medium sized bulbs were produced by the interaction effect of15 and 6 cm inter and intra row spacing. The maximum individual bulb weight (102 g) was produced interaction effect of wider inter and intra row spacing of 25 and 10 cm, respectively. Whereas minimum individual bulb weight (45 g) was produced by combination of 15 and 4 cm inter and intra row spacing, respectively. The combination of inter and intra row spacing of 15 and 4 cm respectively, scored the 1st highest marketable bulb yield and the combination 15 and 6 cm inter and intra row spacing scored the 2st highest marketable bulb yield with non-significant yield difference with interaction of 15 and 4 cm inter and intra row spacing, respectively. Inter intra row spacing beyond 15 and 6 cm did not bring significant bulb yield difference. It implies that inter intra row spacing of 15 and 6 cm are optimum to obtain the highest marketable bulb yield of onion with maximum number of medium sized bulbs. The result revealed that the earlier recommendation (20 and10 cm inter and intra row spacing) produced more number of medium and large sized bulbs with a yield penalty of 8.0 and 10 ton per ha^{-1} compared to interaction of inter row spacing of 15 cm with intra row spacing of 6 and 4 cm, respectively. Therefore, the interaction of inter and intra row spacing of 15 with 6 cm is recommended as a first option for producers wishes to produce maximum bulb yield with maximum medium sized bulbs. It was also confirmed that earlier recommendation (20 and 10 cm inter and intra row spacing) is better as a second option for producers who wishes to produce for export market which requires medium and large sized bulbs.

Conflict of Interests

The authors have not declared any conflict of interests.

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