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GROWTH AND YIELD RESPONSE OF SHALLOT (*Allium cepa var. aggregatum*) VARIETIES TO INTRA-ROW SPACING IN EASTERN AMHARA, ETHIOPIA

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ABSTRACT

Shallot is an important crop as a condiment as well as a source of income for smallholder farmers in Ethiopia. However, the yield of the crop is constrained by a number of factors among which inappropriate plant spacing and lack of improved varieties are the bottlenecks of its productivity in the study area. Therefore, a field experiment was conducted at Densa, Eastern Amhara, and Ethiopia to evaluate the growth and yield response of shallot varieties to intra-row spacing. The treatments consisted of four intra-row spacings (5, 10, 15 and 20 cm) and three shallot varieties (Dz-sht-157-1B, Dz-sht-91-2B, and Yheras). These were laid out in randomized complete block design replicated three times. Data on growth and yield parameters were recorded and subjected to analysis of variance (ANOVA). Results indicated that varying intra-row spacings from 5 to 20 cm increased significantly ($P < 0.01$) all yield characters assessed in all the traits except cured bulb yield (t ha^{-1}) which decreased as a result of increasing intra-row spacing from 5 to 20 cm. Highest total bulb yield (26.20 t ha^{-1}) and marketable bulb yields (25.24 t ha^{-1}) were recorded at the closest intra-row spacing (5 cm). Dz-sht-157-1B variety was superior in terms of leaf number per plant (35.82), average bulb weight (69.08 g), marketable yield (24.46 t ha^{-1}) and total bulb yield (25.17 t ha^{-1}). Hence, based on the result, Dz-sht-91-2B grown at 10 cm intra-row spacing should be adopted by farmers in study area. However, further investigations on multiplications and over years should be made to come up with complete recommendations.

Contribution/Originality: This study contributes to the existing literature by conducting a field experiment at Densa, Eastern Amhara, and Ethiopia to evaluate the growth and yield response of shallot varieties to intra-row spacing.

1. INTRODUCTION

Shallot (*Allium cepa var. aggregatum*), belongs to the family Alliaceae, is an onion like plant that is originated from Western Asia [1]. The crop is grown in more than 170 countries in the world that China and India are the world's largest producers [2]. It is one of the most widely cultivated bulb crops with wide range of climatic and soil adaptation in Ethiopia [3]. The crop is produced traditionally by small farmers in Hararge, Shoa, Arsi, Gojjam, etc. as cash crops and income generating spices for flavoring local dishes. Shallot is also preferred for its shorter growth cycle, better tolerance to disease and drought stresses and longer storage life than the common onion and for its distinct flavor that persists after cooking [4].

In Ethiopia, the production of shallot was 132424.68 ton in 14758.51 ha of land with an average yield of 8.97 t ha^{-1} [5] which is lower as compared to the world average of 18.8 ton ha^{-1} [2]. The area covered by shallot in the Amhara region and north Wollo zone is 12339.39 ha and 463.197 ha with the productivity of 12.84 ton ha^{-1} and 12.7 ton ha^{-1}, respectively [5]. Pests and diseases, coupled with a low level of improved agricultural technology, recurrent droughts, and decreases in soil fertility levels, different cultural practices, inappropriate spacing are some of the major contributors to the low and unstable crop yields in Ethiopia [6]; [7]. Shallot researches in the country were mainly focused on the comparison of the conventional production practices (bulb to bulb) and (transplant to bulb) and to identify adaptable true transplant shallot lines under rain fed conditions [8]. Spacing has effect on different varieties of of shallot as their bulb and leaf growth habit. Dereje, et al. [9] recommended intra-row spacing of 10 cm for *Huruta* and *Negelle* varieties and 15 cm for local variety at which highest marketable bulb yield in low and highland areas of Ethiopia. Shimeles [8] used recommended spacing for onion using double rows of 40 cm between water furrows, 20 cm between rows and 10 cm between plants during his study on the performance of true seed shallot lines under different environments of the country.

To improve shallot production, the agricultural research system of the country has made efforts to generate improved varieties. Dz-sht-157-1B, Dz-sht-91-2B and Yheras varieties are widely grown in Ethiopia [10]. However, these varieties are not distributed to all or most growing areas of the country and are not tested in different agro-ecologies, particularly in the study area. Although bulb yield performance evaluation was undertaken by Shimeles and Lemma [3] in lowland areas of Melkassa and highland areas of Arsinegele, it is very difficult to give general recommendation that can be applicable to the different agro-ecological zones. Optimization of spacing for different varieties of shallot is paramount important that, it avoids strong competition between plants for growth factors, such as water, nutrients and light. In addition, optimum spacing, subsequently optimum plant population, enables use of available cropland without wastage [11].

Densa area is one of the potential areas for shallot production in Eastern Amhara in particular and Ethiopia in general. However, there are no recommended packages with regard to management practices. Shallot is produced in the area; even though lack of planting materials, market accessibility, poor agronomic practices, included intra row spacing are also the major problems. Thus, the yield is 7.8 t ha^{-1}, which is very low as compared to the national average [12].

Several researchers in many countries have shown that varieties and plant spacing had profound effects on the growth and yield of shallot [13]; [14]; [15]; [16]. Nationally recommended intra row spacing of shallot has been 10 cm, the spacing between plants of onion, based on the research done in Melkasa, Zewai and Kulumsa of the country some years back. Nevertheless, in real situation, the produce, which is adopted by farmers, is a bit far (narrower or wider) from the recommendation. There is no recommendation made even in Eastern Amhara region in general and study area in particular with regard to shallot intra-row spacing for certain adapted varieties. Considering the above stated situations the present study was undertaken to determine the response of different varieties of shallot to intra row spacing under Densa, Eastern Amhara conditions.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The experiment was conducted at Densa *Kebele* of *Densa* FTC, Gidan district of Eastern Amhara region during October 2018 to January 2019 under irrigation. The experiment area lies about 12°14' 60.00" N latitude and 39° 09' 60.00" E longitude Figure 1 with altitude of 2200 m.a.s.l [17]. The area experiences bimodal rainfall with *Belg* season from February to March and the main rainy season (*Meher*) from June to September. The area receives average rainfall 900 mm with minimum and maximum temperature 15 to 22°C, respectively [18].

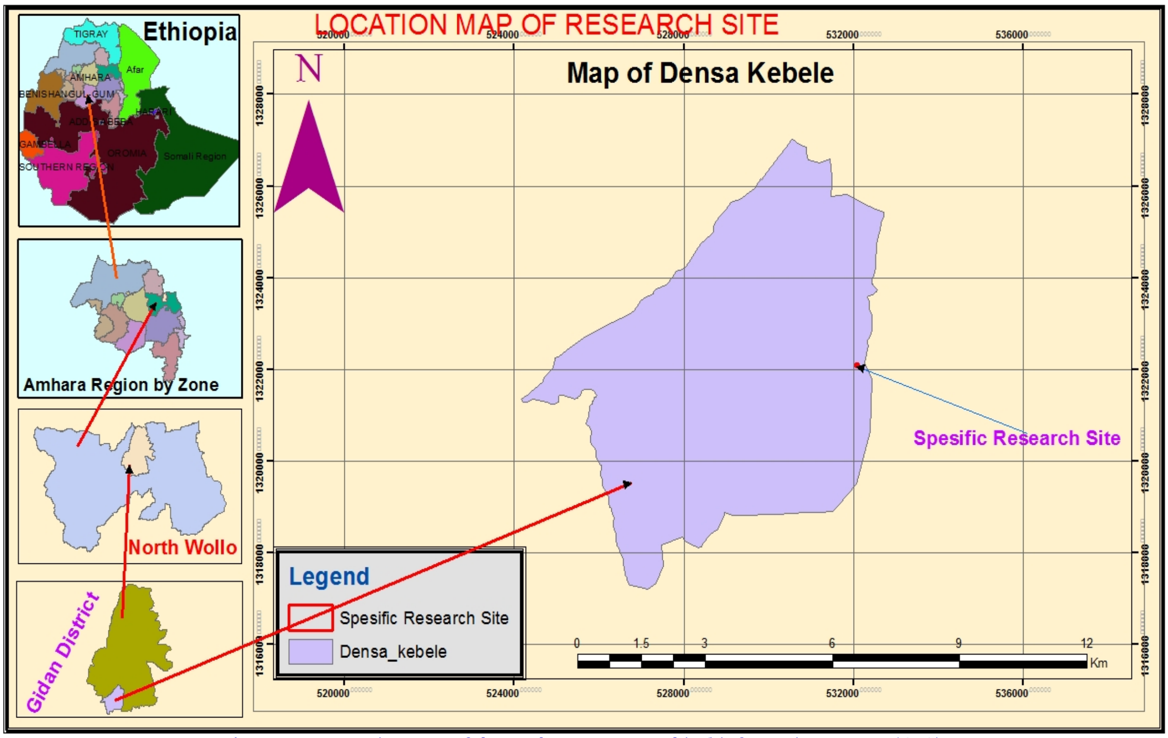

Figure-3.1. Location map of the study area geographical information system (GIS).
Source: Gidan Woreda Agriculture Office (GWAO) [12].

2.2. Treatments and Experimental Design

The experiment consisted of factorial combinations of two factors *viz.-a-viz* intra-row spacing (5, 10, 15 and 20 cm) and varieties (Dz-sht-157-1B, Dz-sht-91-2B and Yheras) laid out in 3×4 factorial combinations arranged in a randomized complete block design (RCBD) with three replications.

2.3. Planting and Agronomic Practices

Shallot varieties *viz-a-viz.*, Dz-sht-157-1B, Dz-sht-91-2B and Yheras were used for the study. Seeds of all varieties were sown in a nursery on well prepared seed bed. When the seedlings were at 3 to 4 leaves stage or 12 to 15 cm height, they were transplanted in the experimental field. Planting was done on ridges of about 25 cm high adopting the recommended spacing of 40 cm between water furrows, 20 cm between rows on the ridge. The plot size was 3 m × 1.8 m accommodating five double rows with 340, 160, 100, and 70 plants per plot for the intra-row spacing of 5, 10, 15, and 20cm, respectively. A distance of 0.5 m was maintained between plots and 1 m between blocks. All cultural practices were employed as per the regional recommendations. During maturity, when 2/3 of the leaves become yellow in color, bulb was harvested and cured for 5 days [19]. Samples were taken from each plot in central rows for data collection.

2.4. Data Collection and Analysis

Data were collected on phenology (days to maturity) vegetative growth parameters (plant height, leaf number/plant), biomass parameters (shoot fresh and dry weight, harvest index) and yield and its components (average bulb weight, bulb length, neck diameter, bulb diameter, bulb dry weight, marketable and unmarketable bulb yield and total bulb yield) using the standard procedures described by IPGRI [20]. All the parameters were collected from ten randomly selected plants of each treatment. The collected mean values of the above growth and yield parameters were subjected to the analysis of variance (ANOVA) using SAS version 9.2 computer software [21]. Whenever the treatment was significant, Fisher's Least Significant Difference (LSD) was used for mean separation at 5% probability level.

3. RESULTS AND DISCUSSIONS

3.1. Days to Physiological Maturity

The main effect of intra-row spacing and varieties had influenced significantly ($P < 0.01$) on days to physiological maturity. Shallot plants grown at narrow intra-row spacing of 5 cm matured earlier than grown at wider intra-row spacing of 20 cm. In general, maturity of shallot plant increased by 8.53% due to the increment of intra-row spacing from 5 to 20 cm Table 1. This might be attributed due to competition for water, light and nutrient in closer spacing, causing early bulb maturity while wider spacing allowed plants to have access for the most growth factors which prolong maturity. The result is in agreement with the findings of Sara, et al. [22] and Fikadu [23] who noted that bulb maturity is advanced by narrow spaced planting, which might be associated with a high leaf area index and hence light interception by the leaf canopy that advance the date of bulb scale initiation. On the other hand, Dz-sht-91-2B followed by Dz-sht-157-1B varieties was late, which matured 142.91 and 134.25 days, respectively, while Yheras variety was earliest with maturity date of 126.16. The varietal difference could be due to the inherent genetic variability of the crop. In line with this, Yemane, et al. [11] reported variations in days to maturity among onion varieties.

3.2. Plant Height

Intra-row spacing and variety significantly ($P < 0.01$) affected plant height. The longest plant (79.16 cm) was recorded from shallot plants grown at 20 cm intra-row spacing, which statistically in party with plant height of 76.33 cm recorded from plants grown at 15 cm intra-row spacing Table 1. Closer spacing might be resulted in competition for growth factors such as water, nutrient and light thus resulting in plants that were short while the wider spaced plants might have adequate space to uptake growth requirements for their growth and development. In agreement with this result, Fikadu [23] obtained the longest plant height (27.28 cm) of shallot at intra-row spacing of 15 cm followed by 24.65 cm with the spacing of 20 cm; while the shortest plants (22.66 cm) at 10 cm intra-row spacing. Moreover, results are also in agreement with the findings of Yemane, et al. [11] and Sara, et al. [22] on onion and Karaye and Yakubu [24] on garlic. Dz-sht-157-1B and Dz-sht-91-2B varieties produced the longest plants than Yheras Table 1. In line with the present findings, Yemane, et al. [11] found significant genotypic variation in plant height. Furthermore, Tegbew [25] indicated the mean plant height of Adama Red (62.25 cm) cultivar was significantly higher than Bombay Red (56.04 cm).

3.3. Leaves Number

The main effect of intra-row spacing and variety did show significance ($P < 0.05$) difference on leaf number per plant. Shallot planted at 20 cm intra-row spacing produced significantly higher leaf number than planted at 5, 10 and 15 cm. Leaf number increased by 72.44% due to the increment of intra-row spacing from 5 to 20 cm Table 1. The higher leaf number per plant recorded at 20 cm intra-row spacing might be attributed to the fact that, plants widely spaced experienced little or no competition for limited environmental resources compared to closely spaced plants. In accordance with the result, Yemane, et al. [11] reported that reported that increasing plant competition significantly decreases leaf number. The authors further justified that when intra-row spacing increases, the number of plants per unit area decrease, resulted in less competition for mineral nutrients, light and moisture leading to vigorous growth, possibly increasing leaf number per plant. Karaye and Yakubu [24] also reported that garlic planted at 15 and 20 cm intra-row spacing produced significantly higher number of leaves per plant than 10 cm intra-row spacing. Dz-sht-157-1B produced higher leaf number per plant (35.82), which statistically in parity with leaf number (33.74) obtained from variety Dz-sht-91-2B Table 1. In line with the present study, Shimeles and Lemma [3] reported that shallot varieties were difference in response to leaf number when tested at two locations.

Table-1. Effect of intra-row spacing and variety on phenology and growth of shallot.

Treatment	Plant height (cm)	Leaf number plant^{-1}	Days to physiological maturity (days)
Intra row spacing (cm)			
5	69.06^{c}	25.18^{d}	129^{b}
10	73.38^{bc}	30.58^{c}	131^{b}
15	76.33^{ab}	35.23^{b}	137.77^{a}
20	79.16^{a}	43.42^{a}	140^{a}
LSD (P< 0.05)	5.29	3.90	6.73
Significance level	**	**	**
Varieties			
Dz-sht-157-1B	78.69^{a}	35.82^{a}	134.25^{b}
Dz-sht-91-2B	75.71^{a}	33.74^{ab}	142.91^{a}
Yheras	69.05^{b}	31.25^{b}	126.16^{c}
LSD (P< 0.05)	4.58	3.37	5.83
Significance level	**	*	**
SE(±)	1.22	1.3	1.72
CV (%)	7.28	11.87	5.12

Note: Means within a column followed by the same letter(s) are not significantly different at 5% level of probability according to List Significant Difference.

3.4. Aboveground Shoot Fresh Weight

The interaction effect of intra-row spacing and variety of shallot significantly (P < 0.05) affected average shoot fresh weight. The highest fresh shoot weight per plant (43.40 g) was obtained when Dz-sht-157-1B grown at 20 cm intra-row spacing. This variety produced 13.77 g more shoot fresh weight when it was grown at wider intra-row spacing (20 cm) than at narrow intra-row spacing (5 cm) Table 2. The result indicated that different varieties of shallot might respond intra-row spacing differently. The highest aboveground shoot weight per plant of Dz-sht-157-1B due to the wider intra-row spacing might be related to leaf number and plant height per plant. The positive and significant correlation between shoot fresh weight and leaf number (r = 0.66**) and shoot fresh weight and plant height (r = 0.49**) (data not presented) can support the above conclusion. The present findings are in line with Fikadu [23]; Ngullie and Biswas [26] and Saurabh, et al. [27] who reported that wider plant spacing gave higher shoot weight per plant.

3.5. Aboveground Shoot Dry Weight

The interaction effect of intra-row spacing and variety of shallot showed significant (P < 0.01) difference on aboveground shoot dry weight. The highest shoot dry weight (4.89 g) was recorded from Dz-sht-91-2B grown at 20 cm intra-row spacing, which statistically in parity with shoot dry weight values of 4.57 g and 4.42 g from Dz-sht-157-1B grown at the same intra-row spacing and at 15 cm intra-row spacing, respectively Table 2. Shallot varieties grown from wider intra-row spacing have competitive advantage that can help to capture the resources, which enhances vigorous vegetative growth subsequently shoot dry weight. The result is elucidated by Shimeles [8] who reported an increase dry matter accumulation of varieties parallel to the increasing intra-row spacing.

3.6. Bulb Diameter

Main effect of intra-row spacing and variety showed significant (P < 0.01) difference in bulb diameter of shallot. The biggest bulb diameter (5.80 cm) was recorded from shallot plants grown with the intra-row spacing of 20 cm, which statistically in parity with bulb diameter of 5.79 cm obtained with intra-row spacing of 15 cm; while the lowest bulb diameter (4.02 cm) was recorded from intra-row spacing of 5 cm Table 3. In general, bulb diameter increased with increasing intra-row spacing. This is due to proper spacing ensures optimum growth and diameter of bulb through adequate utilization of moisture, light, spacing and nutrients. This result is in conformity with Saurabh, et al. [27] who found the biggest bulb diameter (7.06 cm) with 15 cm x 10 cm and the lowest value (5.01 cm) with 7.5 cm x10 cm. Ngullie and Biswas [26] who found the highest bulb diameter from wider intra-row spacing. The trend of decreasing bulb diameter as an intra-row spacing decreased was in consistence with the results reported by Geremew, et al. [28]. On the other hand, the biggest bulb diameter (5.71 cm) was obtained from the variety Dz-sht-157-1B (Table 3). The difference of varieties in bulb diameter might be due to their differences in genetic makeup. The result is in agreement with Shimeles [8]; Shimeles and Lemma [3] and Fikadu [23] who reported that varieties of shallot differed in response to growing environments.

Table-2. Interaction Effects of intra-row spacing and varieties on growth of shallot.

Intra row Spacing (cm)	Varieties	Average fresh shoot weight (g plant^{-1})	Average shoot dry weight (g plant^{-1})
	Dz-sht-157-1B	29.63^{d}	2.65^{e}
5	Dz-sht-91-2B	24.16^{e}	2.45^{e}
	Yheras	28.63^{de}	2.40^{e}
	Dz-sht-157-1B	36.26^{bc}	3.30^{bcd}
10	Dz-sht-91-2B	32.26^{cd}	3.28^{bcd}
	Yheras	32.56^{cd}	2.89^{dce}
	Dz-sht-157-1B	30.20^{d}	4.42^{a}
15	Dz-sht-91-2B	39.20^{ab}	3.47^{bc}
	Yheras	32.86^{cd}	2.83^{de}
	Dz-sht-157-1B	43.40^{a}	4.57^{a}
20	Dz-sht-91-2B	41.16^{ab}	4.89^{a}
	Yheras	33.56^{cd}	3.78^{b}
LSD (P< 0.05)		5.17	0.58
Significance level		*	**
SE(±)		0.98	0.14
CV (%)		9.49	9.93

Note: Means within a column followed by the same letter(s) are not significantly different at 5% level of probability according to List Significant Difference.

3.7. Average Bulb Weight

Main effect of intra-row spacing highly significantly ($P < 0.01$) and variety significantly ($P < 0.05$) influenced average bulb weight. As intra-row spacing increased from 5 cm to 20 cm, average bulb weight increased from 52.15 to 75.55 g Table 3. The increased average bulb weight with increasing intra-row spacing might be due to less competition associated with widely spaced plants that resulted in heavier bulb weight per plant. The result is in line with the findings of Yemane, et al. [11] who noticed that onion mean bulb weight increases with increasing intra-row spacing. Aliyu, et al. [29] reported the increase of mean fresh bulb weight from 54.89 to 84.58 g as the plant spacing increase from 10 to 15 cm. Dz-sht-157-1B variety showed significantly higher average bulb weight (69.27 g), while the lower value (64.18 g) was recorded from Yheras variety Table 3. The observed difference in mean fresh bulb weight among varieties might be due to their genetic variability, which is consistent with the finding of Shimeles [8] and Shimeles and Lemma [3]. Yemane, et al. [11] found the varietal differences in onion on average bulb weight. Geremew, et al. [28] reported that variety Bombay Red produced average bulb weight 104.78 g higher than Adama Red.

3.8. Bulb Dry Weight

The analysis of variance showed that mean bulb dry weight per was significantly ($P < 0.01$) influenced by the main effects of intra-row spacing and variety. As intra-row spacing increased from 5cm to 20cm, the bulb dry weight was also increased from 6.98 g to 9.33 g Table 3. This might be due to the fact that closer spacing between plants resulted in competition for nutrients, moisture and light, thus reducing amount of assimilate produced and stored in the bulbs which subsequently reduced bulb dry weight. Similar result was also reported by Dereje, et al. [9] who observed that shallot bulbs planted at 20cm intra-row spacing produced greater bulb dry weight per plant than those planted at intra-row spacing of 15 and 10 cm. The result is also consistent with the findings of Sara, et al. [22] on onion, Karaye and Yakubu [24] on garlic and Abubaker [30] on bean. On the other hand, Dz-sht-157-

1B variety gave significantly higher bulb dry weight (9.04 g) than Dz-sht-91-2B and Yheras that exceeded by about 7 and 23%, respectively. In this regard, varietal could have different potentials to produce bulb dry weight due to to their genetic potential. Similarly, Shimeles [8]; Shimeles and Lemma [3] observed varietal differences in bulb dry weight. Furthermore, Tibebu, et al. [31] reported mean bulb dry weight per plant for Adama Red lower than Bombay Red.

Table-3. Main effects of intra-row spacing and varieties on yield component of shallot.

Treatment	Average bulb weight (g)	Bulb diameter (cm)	Bulb dry weight (g plant^{-1})
Intra row spacing (cm)			
5	52.15^{c}	4.02^{c}	6.98^{c}
10	69.53^{b}	4.97^{b}	8.15^{b}
15	72.81^{ab}	5.79^{a}	8.67^{ab}
20	75.55^{a}	5.80^{a}	9.33^{a}
LSD (P< 0.05)	4.76	0.63	0.66
Significance level	**	**	**
Varieties			
Dz-sht-157-1B	69.27^{a}	5.71^{a}	9.04^{a}
Dz-sht-91-2B	69.08^{a}	4.84^{b}	8.45^{b}
Yheras	64.18^{b}	4.88^{b}	7.36^{c}
LSD (P< 0. 05)	4.12	0.55	0.57
Significance level	*	**	**
SE(±)	1.74	0.17	0.21
CV (%)	7.22	12.62	8.21

Note: Means within a column followed by the same letter(s) are not significantly different at 5% level of probability according to List Significant Difference.

3.9. Bulb Neck Diameter

Bulb neck diameter is significantly ($P < 0.05$) influenced by the interaction of intra-row spacing and variety. The highest bulb neck diameter (3.66 cm) was recorded from Dz-sht-157-1B grown at intra-row spacing of 20 cm, which statistically in parity with bulb neck diameter obtained from Dz-sht-91-2B and Yheras at the same intra-row spacing Table 4. The result is supported by the findings of Broome [32] who reported that neck diameter of different Allium species plants grown at 20 cm was larger than plants grown at 15 cm which in turn were larger than plants grown at 10 cm. On the contrary, neck diameter of onion was not affected by intra-row spacing as reported by Dereje, et al. [9].

3.10. Harvest Index

The interaction of intra-row spacing and variety had significant ($P < 0.05$) effect on harvest index of shallot. The highest harvest index (73.77%) was obtained from the Dz-sht-157-1B grown at 10 cm intra-row spacing, while the lowest value (67.17%) was recorded from Dz-sht-91-2B grown at 20 cm intra row spacing Table 4. The result illustrated that higher harvest index was recorded from varieties grown at narrow intra-row spacing. This might be, due to presence of shorter leaf and plant height and thin leaf diameter in narrow spacing reduced the above ground biomass and resulted in higher harvest index. Lower harvest index due to might also be the existence of higher number of leaves, widest leafs and widest pseudo stem at wider spacing. In accordance with the result, Dereje, et al. [9] found higher harvest index in case of local grown at narrow intra-row spacing due to the presence of shorter leaf and plant height and thin leaf diameter, which reduced the above ground biomass, whereas in case of *'Negelle'* and *'Huruta'*, production of smaller number of leaves and relatively larger bulbs accounted the highest harvest index per plant. Similar results were reported by Agele, et al. [33] on sunflower, Kabir and Sarkar [34] on mungbean who reported a significant interaction effect on harvest index and the highest value recorded from varieties at closer spacing probably due to the reduced vegetative biomass.

Table-4. Interaction effects of intra-row spacing and varieties on yield component of shallot.

Intra row Spacing (cm)	Varieties	Harvest Index (%)	Neck diameter (cm)	Unmarketable bulb yield (t ha^{-1})
	Dz-sht-157-1B	73.33^{a}	2.56^{e}	0.90^{b}
5	Dz-sht-91-2B	74.04^{a}	2.03^{f}	1.10^{a}
	Yheras	73.47^{a}	2.76^{de}	0.88^{b}
	Dz-sht-157-1B	73.77^{a}	3.16^{c}	0.70^{cd}
10	Dz-sht-91-2B	70.92^{abc}	3.30^{bc}	0.86^{b}
	Yheras	71.11^{abc}	3.06^{cd}	0.72^{c}
	Dz-sht-157-1B	68.24^{cd}	3.56^{ab}	0.59^{cde}
15	Dz-sht-91-2B	71.77^{ab}	3.36^{abc}	0.59^{def}
	Yheras	73.05^{a}	3.30^{bc}	0.54^{f}
	Dz-sht-157-1B	68.82^{bcd}	3.66^{a}	0.54^{ef}
20	Dz-sht-91-2B	67.17^{d}	3.60^{ab}	0.53^{def}
	Yheras	67.52^{d}	3.53^{ab}	0.54^{f}
LSD (P< 0.05)		3.24	0.35	0.08
Significance level		*	*	**
SE(±)		0.56	0.08	0.03
CV (%)		2.8	6.59	7.23

Note: Means within a column followed by the same letter(s) are not significantly different at 5% level of probability according to List Significant Difference.

3.11. Unmarketable Bulb Yield

Unmarketable bulb yield was significantly ($P < 0.01$) influenced by the interaction of intra-row spacing and variety. The highest unmarketable bulb yield (1.10 t ha^{-1}) was recorded from Dz-sht-91-2B grown at 5 cm intra-row spacing Table 4 .

High unmarketable yield in closely spaced plants could be due to inter-plant competition resulting in more small sized bulbs that negatively affected the marketable yield and favored the production of small sized bulbs than wider spacing. This finding is in agreement with Geremew, et al. [28] and Dereje, et al. [9] who reported similar results unmarketable and marketable bulb yield could be affected by both varietal differences and intra-row spacing.

3.12. Marketable Bulb Yield

Highly significant ($P < 0.01$) differences were observed among intra-row spacing and shallot varieties on the marketable bulb yield. As intra-row spacing increased from 5 to 20 cm, marketable yield of shallot decreased from 25.24 to 17.60 t ha^{-1}. However, marketable yield obtained from 5 cm intra-row spacing was statistically in parity with marketable yield recorded from 10 cm intra-row spacing Table 5. Narrower intra-row spacing, subsequently higher plant population per unit area might has an impact on marketable bulb size; hence, the higher the plant population, the smaller bulb size could be produced. This result is supported by Seck and Baldeh [35]. On the contrary, Tendaj [16] reported an increment of marketable yield from 2.1 to 10.4 t ha^{-1} due to increment of in intra-row spacing of shallot from 5 to 20 cm. Furthermore, the production of large sized tubers due to wider intra-row spacing of 32.5 cm reported by Carlson, et al. [36] disagreed this finding.

The highest marketable yield (24.46 t ha^{-1}) was recorded in Dz-sht-157-1B, which however, statistically in parity with the marketable yield (23.27 t ha^{-1}) recorded in Dz-sht-91.2B, while the lowest marketable yield (19.54 t ha-1) was recorded in variety Yheras Table 5. The difference in marketable bulb yield due to variety could be the fact that varieties perform differently under divers agro-climatic conditions and various cultivars of the same species grown even at the same environment often yield differently. In this regard,Jilani, et al. [37]; Dereje, et al. [9] ;Yemane, et al. [11] and Shimeles and Lemma [3] reported that performance of a cultivar mainly depends on the interaction of genetic makeup and environment.

3.13. Total Bulb Yield

The main effect of variety and intra-row spacing had significant (P<0.01) effect on total bulb yield of shallot. Bulb yield was decreased by 29.39% due to the increment of intra-row spacing from 5 to 20 cm. Hence, the highest total bulb yield (26.20 t ha^{-1}) was obtained at 5 cm intra-row spacing, which statistically similar with total bulb yield (25.75) t ha^{-1}) recorded at the intra-row spacing of 10 cm Table 5. The positive increase in bulb yield at closer spacing might be ascribed to increase plant population per unit land area while the decrease in bulb yield at wider intra-raw spacing could be associated with decreased plant population per unit land area. Unlike that of individual bulb weight and dimension, the total bulb yield per unit area decrease with increasing intra-row spacing. It can thus be seen that, the total yield per unit area depends not only on the performance of individual plants but also on the number of plants per unit area as confirmed in this study. Similar results were observed by Karaye and Yakubu [24] in garlic, Dereje, et al. [9] in shallot and Yemane, et al. [11] in onion. Furthermore, Tendaj [16] who reported that an increase in intra-row spacing of shallot from 5 to 20 cm resulted in reduction of total yield from 36.0 t ha^{-1} to 23.9 t ha^{-1}. In contrast to the results of the present study, Kabir and Sarkar [34] also reported that interaction effects between variety and spacing were significant for seed yield of mungbean and the highest value was recorded at wider spacing which has less population density.

The highest total bulb yield (25.17 t ha^{-1}) was obtained from variety Dz-sht-157-1B followed by Dz-sht-91-2B (24.04 t ha^{-1}). The lowest total bulb yield (20.22 t ha^{-1}) was recorded from variety Yheras Table 5. This might be due to the fact that varieties have different yield potential as well as genetic and environmental interaction effect. The result is in agreement with the findings of Jilani, et al. [38]; Dereje, et al. [9]; Shimeles [8]; Tibebu, et al. [31] and Shimeles and Lemma [3].

Table-5. Main Effects of intra-row spacing and varieties on yield of shallot.

Treatment	Marketable bulb yield (t ha^{-1})	Total bulb yield (t ha^{-1})
Intra row spacing (cm)		
5	25.24^{a}	26.20^{a}
10	24.99^{a}	25.75^{a}
15	21.54^{b}	22.14^{b}
20	17.60^{c}	18.50^{c}
LSD (P< 0.05)	2.34	2.32
Significance level	**	**
Varieties		
Dz-sht-157-1B	24.46^{a}	25.17^{a}
Dz-sht-91-2B	23.27^{a}	24.04^{a}
Yheras	19.54^{b}	20.22^{b}
LSD (P< 0.05)	2.03	2.01
Significance level	**	**
SE(±)	0.71	0.73
CV (%)	10.71	10.29

Note: Means within a column followed by the same letter(s) are not significantly different at 5% level of probability according to List Significant Difference.

4. CONCLUSION

Shallot is one of the popular and the most cultivated vegetables in Ethiopia in general and in Eastern Amhara region in particular. Shallot producers in the study area produce shallot as a cash crop using non-uniform intra-row spacing based on the existing indigenous knowledge. The study was thus conducted to investigate the effect of different intra-row spacings on yield and yield components of three shallot varieties and to recommend options for farmers in and around the study area. Results of the study showed that main effects of intra-row spacing, varieties as well as their interactions had considerable influences on different parameters. Yheras was found to be 17 days earlier than the latest varieties of all and followed by Dz-sht-157-2B which is earlier in 9 days than the latest by Dz-sht-157-2B. Leaf number was increased by 72.44% due to the increment of intra-row spacing from 5 to 20 cm.

Intra-row spacing of 5 and 10 cm had higher marketable yield than 15 and 20 cm intra-row spacing. The highest unmarketable bulb yield (1.10 t ha^{-1}) was recorded from Dz-sht-91-2B grown at 5 cm intra-row spacing. As intra-row spacing increased from 5 to 20 cm, average bulb weight increased from 52.15 to 75.55 g. The highest total bulb yield (26.20 t ha^{-1}) was obtained at 5 cm intra-row spacing, which statistically similar with total bulb yield (25.75) t ha^{-1}) recorded at the intra-row spacing of 10 cm. The highest total bulb yield (25.17 t ha^{-1}) was obtained from variety Dz-sht-157-1B followed by Dz-sht-91-2B (24.04 t ha^{-1}). The finding suggested it is better to use intra-row spacing of 5 and 10 cm as highest marketable bulb yields were recorded. Besides, the ultimate goal of shallot production is profitably through yield enhancement, the result revealed that Dz-sht-157-1B and Dz-sht-91-2B varieties appeared to be superior marketable yield at the study area. However, further investigation must be made under different seasons in order to fully recommend the results of the present study which is based on one season and location.

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