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Research Article

Effects of Varieties and Different Environments on Growth and Yield Performance of Shallot (*Allium cepa* var. *aggregatum*)

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Shallot (*Allium cepa* var. *aggregatum*) is one of the major cash crops produced in the Amhara region, including East Gojjam Zone, Ethiopia. However, the shallot is being out of production, and there are limited research efforts concerning the influence of the growing environment on shallot varieties. Thus, the objective of the study was to identify adaptable and high-yielding shallot varieties across different agroecologies/location in the East Gojjam Zone of Ethiopia. The experiment was conducted at three locations (Debre Markos, Wonka, and Yelam Gej) during 2019/20 and 2020/21 growing seasons. The study consists of four shallot varieties (Minjar, Huruta, Negelle, and local). The experiment was conducted in a randomized complete block design with three replications. Data on growth, yield, and yield component parameters were recorded and analyzed using SAS Computer Software version 9.0. The present results indicated that the highest plant height, leaf length, number of shoots per plant, number of bulblets per bulb, average bulb weight, total yield, and marketable yield per hectare were recorded from improved shallot varieties Minjar, Negelle, and Huruta. Thus, Minjar, Negelle, and Huruta were better performed for growth, yield, and yield components at all testing locations. Thus, Minjar, Negelle, and Huruta were found to be superior in yield and yield components at all testing locations and were thus suggested to be used by the growers in the study area. It would be advisable to evaluate the varieties in the participatory varietal trail for further dissemination of varieties to shallot growers in the study area.

1. Introduction

Shallot (*Allium cepa* var. *aggregatum*) belongs to the family *Alliaceae* and is believed to be originated from West Asia [1]. Shallot is primarily consumed for its unique flavor or ability to enhance other foods' flavors. Shallot had a significant contribution to the nutritional value of the human diet and has medicinal properties. It is rich in sugar, protein, fat, calcium, potassium, phosphorus, sulfur, iodine, fiber, silicon, and vitamins [2, 3]. It reduces the cholesterol in the blood, and its juice is given in pulmonary tubers, close rheumatism, sterility, impotency, cough, and red eyes [4].

The bulbs of the shallot plant produce more than two and up to 15 small bulbs (bulblets), which are in aggregated form [5]. Shallot is tolerant to a wide range of soils with a pH of 6-7; loose, sandy soils with a high level of organic content are preferable [6]. In Ethiopia, shallot has long been grown by subsistent farmers in the mid- and high altitudes (1800 to 2200m.a.s.l) for seasoning foods and as a source of income [7].

Ethiopia has enormous potential for the cultivation of horticultural crops in general and vegetables in particular on a small scale as well as for commercial production. Shallots are the most widely cultivated bulb crops in different parts of Ethiopia as a substitute for bulb onions. The cultivation of shallot is preferred by farmers compared with onion for its ability to propagate in a vegetative way, shorter growth cycle, disease tolerance, better storage life, and distinct flavor that persists after cooking [8, 9]. Shallot has a wide range of climatic and soil adaptations and is cultivated under rain-fed and irrigated conditions in different agroclimatic regions [10, 11]. It is one of the most widely cultivated cash crops and

is traditionally cultivated in some parts of the country (Hararge, Shoa, Arsi, and Gojjam, etc.) by small farmers as an income-generating spice crop for flavoring local dishes.

According to Getachew and Asfaw [12], BoARD [13], and Ademe et al. [14], the shallot is among the major cash crops produced in the Amhara region including East Gojjam Zone under irrigation and rain-fed conditions. In Ethiopia, the total area under shallot reached 14758.51 ha of land, and the production is estimated to be over 132424.68 tons of fresh bulbs with an average yield of 8.97 t/ha (CSA, 2017). Despite its high economic importance, the national average bulb yield of shallot under farmer's condition is about 8.97 t/ha with poor bulb quality (mixed varieties, varying in size, color, shape, and storability) compared to 25 t/ha obtained under good management practice. In the Amhara region, the area covered by shallot is 12339.39 ha with a productivity of 12.84 tons/ha. However, its productivity is lower than the world average of 19.32 t/ha [7, 15, 16].

There are several factors that limit shallot productivity. These include a lack of improved technology, low attention to the crop, poor agronomic practices, and availability of quality planting materials, and a lack of improved production, and protection technologies [7]. Furthermore, the lack of improved preharvest and postharvest management practices, diseases, and insects have also contributed to low yield and quality [17]. Due to these factors in the study area, full production capacity (yield potential) has not been exploited, and research efforts are inadequate and insufficient on the influence of diverse growing environments on shallot varieties. Hence, to reduce shallot production problems, different cultivars often require specific agroecological conditions for maximum production potential. Thus, the objective of the study was to identify adaptable and high-yielding shallot varieties across different agroecologies in the East Gojjam Zone of Ethiopia.

2. Materials and Methods

2.1. Description of the Experimental Area. The experiment was conducted at three different agroecologies (Debre Markos, Wonka, and Yelam Gej districts) in two consecutive years (2019/2020 and 2020/2021). The locations were selected based on the shallot production potential and represent distinct agroecologies. The three selected major shallot-producing districts in the East-Gojjam Zone are as follows: Debre Markos testing site is geographically located at 10°19′59″N 37°44′53″E. The altitude of the study area was 2450 m.a.s.l. The minimum and maximum temperatures were 11°C and 24°C, respectively. The minimum and maximum rainfalls were 1300 mm and 1380, respectively. The soil type of the study site is nitisols and clay in its textural class [18].

Wonka testing site is geographically located at 10°10′00″ and 10°40′00″N latitude and 37°30′00″ and 37°54′00″E longitude, and the altitude of the testing site was 2300m.a.s.l. The minimum and maximum temperatures were 6.9°C and 22°C, respectively. The mean annual rainfall amount ranges between 1157.7 and 1753.0 mm. The soil type of the study site is nitisols.

Yelam Gej testing site is geographically located at 10°02′33″N 37°44′33″E and 2181°m.a.s.l. The minimum and maximum temperatures were 16°C and 30°C, respectively. The average rainfall was 750 mm. The soil type of the study site is nitisols.

The rainfall was well distributed throughout the cropping season; however, no rain was experienced during January, February, March, and April during both seasons (Figure 1(a)). The highest maximum temperature recorded from Debre Markos testing site, followed by Yelam Gej and Wonka during 2020/2021 growing season and from Yelam Gej during 2021/2022 season (Figure 1(b)). The minimum mean temperature was recorded from Wonka testing site, followed by Debre Markos and Yelam Gej during 2020/2021 growing season, while during 2021/2022, the minimum mean temperature was recorded from Debre Markos testing site from January to April (Figure 1(c)).

2.2. Experimental Materials and Procedures. The experiment consists of four shallot varieties such as Huruta, Minjar, Nagelle, and local as a check which are propagated by bulbs used as planting material. The planting materials except local were obtained from a reliable source Debre Zeit Agricultural Research Center (DZARC). The local variety was purchased from the Debre Markos town market (Table 1). The experiment was conducted for two consecutive years from 2019/2020 to 2020/2021 at three testing sites. Four shallot varieties were laid out in a randomized complete block design (RCBD) with three replications in each location. Treatments were assigned to the experimental plots randomly.

Bulbs were obtained and stored for planting. At planting time, cured, medium-sized (20 to 30 g) bulbs were sorted and graded. Healthy and clean bulbs of each variety were selected and planted [8].

Irrigation water was applied to all plots on the day of planting by using a watering cane once a day (early morning). The bulbs/seedlings were spaced 40 cm × 20 cm × 10 cm double row, row, and plants, respectively. The space between the block and between plots will be 1 m and 0.5 m, respectively. There were four rows per plot and 10 plants per rows for a total of 40 plants per plot. The size of each experimental plot was 1 m^2 (1 m wide and 1 m length). Fertilizers were applied according to the national recommendation at the rate of 200 kg DAP at planting and 100 kg of urea. Urea was applied in the split application, 50% of urea the time of planting and the other 50% at one month after planting [19, 20].

2.3. Data Collected. Measurements of the growth, yield, and yield component parameters were recorded at physiological maturity and harvesting time.

(1) Plant height (cm): it was measured using a ruler from the soil surface to the tip of the longest mature leaves at physiological maturity

(2) Leaf length (cm): it refers to the length of the longest leaf, which was measured using a ruler from the sheath to the tip of the leaf at physiological maturity

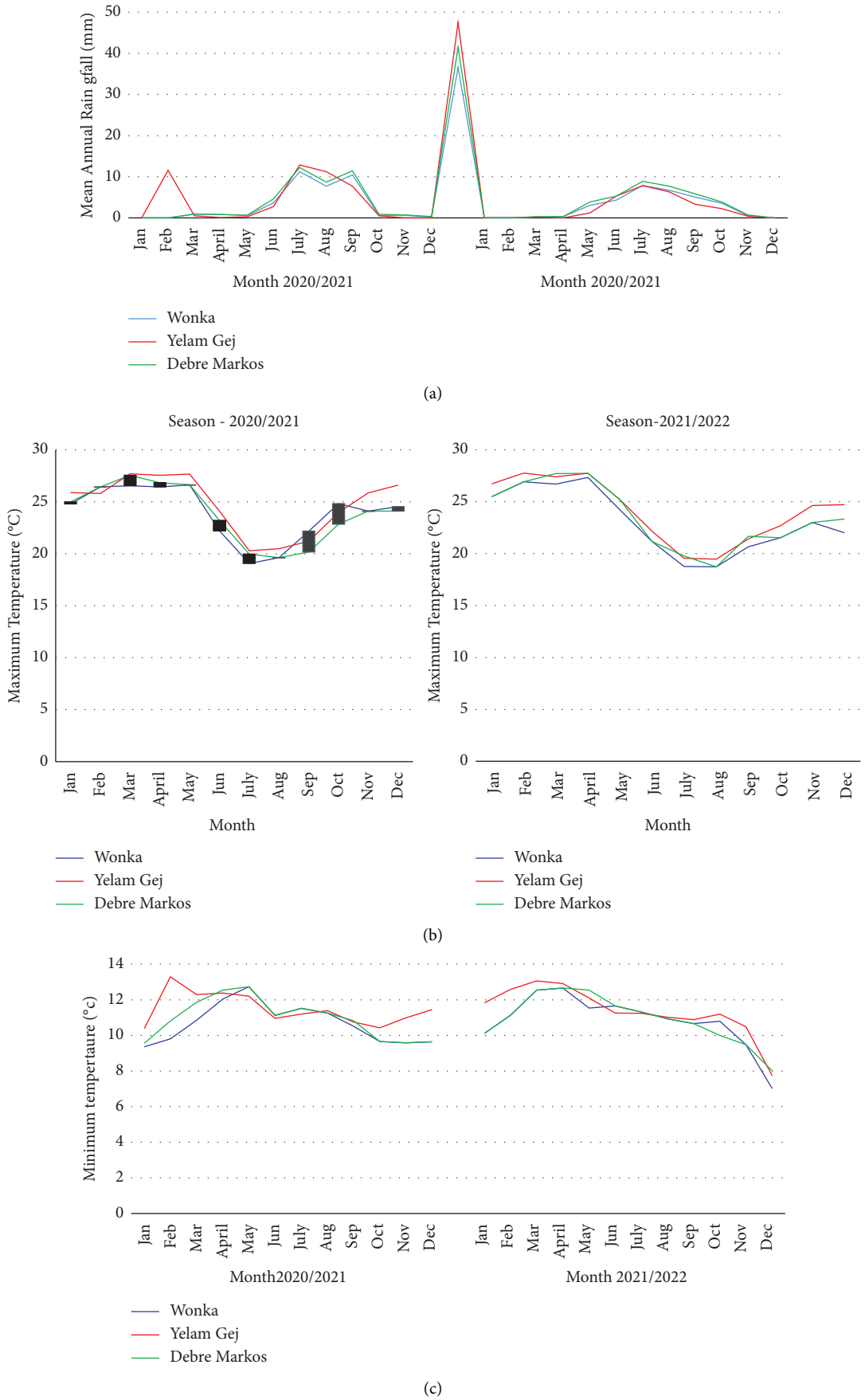

Figure 1: (a) Rainfall amount, (b) maximum temperature, (c) and minimum temperature of study area in cropping seasons of 2020/2021 and 2021/2022.

Table 1: Variety name and year of release.

Variety name	Year of release	Method of propagation	Area of adaptation		Maturity days
			Altitude (m)	Rain fall (mm)	
Minjar	2009	Bulb	1600–2000	>700 mm	101
Negelle	2004	Bulb			
Huruta	1999	Bulb	1800–2200	600–800	95–120
Local		Bulb			

Source: MoANR [13].

(3) Leaf number per plant: it refers to the total count of leaves per plant at maturity

(4) Stem number per hill: it was measured by counting the number of stems/hills

(5) Days to physiological maturity: it refers to the actual number of days from planting to a day at which more than 85% of the plants in a plot showed yellowing of leaves [21]

(6) Bulb neck diameter (cm): it was measured by using a caliper at physiological maturity

(7) Average bulb weight (g): it was computed by weighing ten marketable bulbs after curing and calculating the average

(8) The number of bulblets per bulb: it was the average number of bulblets of 10 bulbs from each plot

(9) Bulb length: the average diameter of 10 bulbs from each plot was measured after curing using a digital caliper

(10) Bulb diameter (mm): it was measured at the widest point (middle portion) of the bulb and the average diameter of 10 bulbs from each plot will be measured after curing using a digital caliper

(11) Marketable bulb yield (t/ha): bulbs having a diameter of ≥18 mm were considered as marketable yield according to the procedure followed by Woldetsadik et al. [8]

(12) Unmarketable bulb yield (t/ha): damaged bulbs <18 mm diameter will be graded as unmarketable according to the procedure followed by Woldetsadik et al. [8] In addition, undersized, defected, and diseased will be graded as unmarketable

(13) Total yield (t/ha): this was measured from the middle two rows (20 plants) of each plot after curing and transformed to tones per hectare.

2.4. Data Analysis. The data collected on different growth and yield parameters were first checked for meeting all ANOVA assumptions for normality of distribution and homogeneity of variance and subjected to the analysis of variance (ANOVA) by using the PROC MIXED procedure of the SAS version 9.0 computer software [22]. Varieties and location (agroecology) were considered fixed effects while block and season were considered as random effects. The combined analysis of variance over seasons and locations was computed for the parameters that show homogeneous variances. For the rest of the parameters, separate analysis was done for each year and for each location to identify their effect on the response variables. The interaction effects between the main effects (variety by location) were presented only when there is a statistically significant difference. In the absence of significant interactions, the main effects were presented. When the analysis showed significant ($p \leq 0.05$), mean separation was carried out using the LSD (least significance difference test) at a 5% significance level [23].

3. Results and Discussion

The effect of varieties and growing environment was evaluated with respect to growth, yield, and yield attributes of shallot and the results obtained are presented accordingly.

3.1. Plant Height (cm) and Leaf Length (cm). The combined analysis of variance over the year and location indicated that plant height was significantly ($p < 0.01$) different between varieties and ($p < 0.0001$) locations. However, the interaction between varieties, growing season, and location did not show a significant difference (Table 2). On the other hand, leaf length was significantly ($p < 0.01$) different between varieties, growing season, and location. However, the locations and interactions between varieties and locations did not show a significant difference ($p > 0.05$) (Table 2). The highest plant height (33.94 cm) was recorded from the variety Minjar. However, it was not significantly different from Negelle (31.27 cm). While the lowest plant height (25.88 cm) was recorded from the local variety, the highest plant height was recorded at the Debre Markos testing site (33.02 cm) and the Yelam Gej testing site (32.97 cm). Similarly, the highest leaf length (29.9 cm) was recorded from the variety followed by variety Minjar (25.92 cm) while the smallest leaf length (22.81 cm) was recorded from the local check. Debre Markos site recorded the highest leaf length (28.67 cm), followed by the Wonka and Yelam Gej testing sites (Table 4).

The highest plant height and leaf length were recorded at Debre Markos testing site compared to Wonka and Yelam Gej. The difference between varieties for plant height and leaf length was due to the genotypic difference and their response to different environmental conditions. The result is in agreement with the findings of Hailu et al. [24], and Esuyawkal-Moges and Biruk-Masrie [25], who reported a significant difference between shallot varieties on plant height and leaf length. Hailu et al. [24] also reported local variety attained the shortest height.

Table 2: Mean squares values and significance level for growth traits of shallot.

Source of variation	Degree of freedom	Plant height (cm)	Leaf length (cm)	Leaf number/plant	Shoot number/plant	Days to physiological maturity
Block ($L * Y$)	12	2.13 ns	28.70 ns	10.39 ns	31.85 ns	37.04**
Variety (var)	3	218.47**	118.42**	37.11**	51.81**	90.75***
Year (y)	1	22.22 ns	186.22**	329.38***	1223.06***	696.88***
Location (loc)	2	7.5.22***	145.89**	706.39***	1151.63***	3200.16***
Var * year	3	29.33 ns	8.08 ns	20.53 ns	0.51 ns	84.33***
Loc * ear	2	22.22 ns	347.44**	329.38***	1183.31***	696.88***
Loc * var	6	45.52 ns	16.91 ns	17.03 ns	6.78 ns	35.09**
Var * loc * year	6	9.62 ns	11.21 ns	15.82 ns	3.16 ns	35.09***
Error	46	17.89	18.53	7.86	246.93	9.4
R^2	0.57	0.81	0.67	0.88	0.92	0.95

Ns = nonsignificant; *, **, and ***indicate significant difference at probability levels of 5%, 1%, and 0.1%, respectively.

Table 3: Mean square values and significance level for yield and yield component traits of shallot.

Source of variation	DF	Bulb neck diameter (cm)	Bulblet number/bulb	Average bulblet weight (g)	Bulb diameter (cm)	Bulb length (cm)	Average bulb weight (kg)	Total yield (t/ha)	Marketable yield (t/ha)
Block ($L * S$)	12	0.16**	3.20 ns	5428.46*	0.36 ns	2.24**	214.34 ns	14.32 ns	12.47 ns
Variety (var)	3	0.08*	16.56***	31153.54***	1.18***	6.17***	540.95**	252.42***	259.339***
Season (s)	1	0.04 ns	5.36 ns	82680.07***	0.68**	0.98 ns	243247.83***	52.56 ns	124.55**
Location (loc)	2	2.67***	1.01 ns	74512.41***	3.76***	4.25***	143867.25***	1671.54***	1457.03***
Var * season	3	0.05 ns	3.37 ns	3290.80 ns	0.068 ns	0.53 ns	534.99**	190.38**	201.01**
Loc * season	2	0.04 ns	5.36 ns	82680.07***	0.68**	0.98 ns	143727.12***	558.09***	124.55**
Loc * var	6	0.09**	2.05 ns	5115.95**	0.36**	0.91 ns	176.21 ns	59.56*	61.34**
Var * loc * season	6	0.05 ns	4.46 ns	2855.13 ns	0.16 ns	0.24	175.19 ns	133.17**	143.82**
Error	46	0.02	1.79	1678.77	0.117	0.339	93.43	25.59	25.16
R^2	0.57	0.84	0.59	0.87	0.76	0.73	0.99	0.85	0.79

Ns = nonsignificant; *, **, and ***indicate significant difference at probability levels of 5%, 1%, and 0.1%, respectively.

3.2. Leaf Number per Plant. Analysis of variance for the combined data indicated that varieties, growing environment, and season had shown highly significant difference ($p < 0.001$) for the mean number of leaves per plant at physiological maturity. The interaction of growing location by season very highly significantly affects the number of leaves per plant. However, the interaction of varieties with growing season and location did not significantly influence leaf number per plant (Table 2).

During the year 2019/2020, the highest mean leaf number per plant was recorded from variety Minjar at Debre Markos (11.33), which was statistically similar to varieties Minjar (9.58) and variety Negelle (10.91) at the Wonka site. The lowest and statistically similar leaf number per plant was recorded from local checks at Debre Markos, Wonka, and Yelam Gej testing sites. On the other hand, during 2020/21 the leaf number per plant was not significantly different (Table 5). The variation in growth parameters among varieties might be due to their genetic differences. The result is in agreement with the findings of Esuyawkal-Moges and Biruk-Masrie [25], who reported the difference between varieties for leaf number per plant. Shimeles and Lemma [26] also illustrated shallot varieties were the difference in response to leaf number per plant at two testing locations. Hailu et al. [24] also reported the difference in leaf numbers between shallot varieties. However, in contrast to the present study, they reported that Minjar varieties produced a small number of leaves per plant.

3.3. Number of Shoots per Plant. The analysis of variance revealed that the main effects of variety, growing location, and season highly significantly ($p < 0.01$) influenced number of shoots per plant of shallot (Table 2). The main effect result indicated that the highest number of shoots per plant was recorded from variety Minjar, Negelle, and Huruta while the lowest number of shoots per plant was recorded from a local check. In addition, the maximum number of shoots per plant was recorded from the Wonka testing site, followed by the Debre Markos and Yelam Gej testing sites. During 2020/2021 growing season the maximum number of shoots per plant was recorded (Figure 2). The variation in shoot number per plant between varieties might be due to the fact that different varieties, with their genetic makeup variation responded differently to different factors. The difference on shoot number per plant might be due to inherent variations in the number of bulblets per bulb on onion which is influenced by genetically [27].

Table 4: Main effect of variety and location on the plant height (cm) and leaf length (cm) of shallot (combined analysis over year and location).

	Plant height	Leaf length
Variety		
Minjar	33.9491[a]	28.9[a]
Negelle	31.2176[ab]	25.92[b]
Huruta	28.4306[bc]	24.60[bc]
Local	25.8843[c]	22.81[c]
LSD (5%)	4.27	2.88
Significance level	**	**
Location		
Debre Markos	33.0208[a]	28.67[a]
Wonka	32.9792[a]	23.44[b]
Yelamgej	23.6111[b]	24.97[b]
LSD (5%)	3.69	2.5
Significance level	***	**
Year		
2019/2020	30.42	23.95[b]
2020/2021	29.31	27.16[a]
LSD (5%)	3.01	2.04
Significance level	ns	**
CV (%)	19.73	16.84

Means followed by the same letter(s) within the same column are not significantly different.

Table 5: Interaction effect of shallot varieties and location on leaf number per plant during the years 2019/2020 and 2020/2021.

Varieties	Leaf number per plant					
	The year 2019/2020			The year 2020/2021		
	Debre Markos	Wonka	Yelam Gej	Debre Markos	Wonka	Yelam Gej
Minjar	11.3333[a]	10.9167[ab]	4.111[g]	23.66	9.58	5.00
Negelle	9.0000[bc]	9.5833[abc]	4.333[ef]	14.50	8.16	4.55
Huruta	8.8333[bcd]	8.0833[cde]	6.3768d[ef]	27.83	9.08	5.11
Local	6.6667[ef]	6.0000[fg]	4.111[g]	21.16	7.75	3.88
LSD (5%)		1.124832				
CV (%)		18.46			29.36	
Significance level		**			ns	

Means followed by the same letter(s) within the same column are not significantly different.

3.4. Days to Physiological Maturity. Analysis of the variance table showed that the main effect as well as interaction effect of variety with growing location and season showed a highly significant effect on days to physiological maturity of shallot (Table 2).

Variety local (112.4 days from planting) and Variety Minjar (111.4 days from planting) took the maximum period of physiological maturity. Variety Huruta and Negelle took the shortest period of maturity (107.5 and 109 days after planting), respectively. The minimum average number of days (98.75 days) to physiological maturity was recorded at the Wonka testing site, followed by the Yelam Gej site (109.7 days). Debre Markos testing site took the maximum number of days (121.8 days) to physiological maturity (Figure 3). Local check was a longer maturity day by 3 and 4 days than the earliest maturing variety Negelle and Huruta, respectively. The Wonka testing site matures earlier by 23 days compared with Debre Markos testing site. The variation of maturity date between growing conditions was due to the highest maximum temperature at the time maturity from September to November during both seasons (Figure 1). Similarly, the variation of maturity date between shallot varieties might be due to their inherent genetic difference.

Additionally, during 2019/20 Variety Negelle took the shortest period of maturity (97.33 days from planting) and Huruta (95.66 days), which was on par with that of Mingar (98.66 days) and Negelle (100.33 days) at Wonka. On the other hand, the local variety at Debre Markos took the maximum (124 days) to reach physiological maturity, followed by the variety Minjar (113.67 days) at Debre Markos and Yelam Gej (113.67 days). During 2020/21 Variety Minjar took the shortest period of maturity (95 days from planting), which was on par with that of Mingar (98.66 days) and Negelle (100.33 days) at Wonka. On the other hand, the variety Minjar at Debre Markos took the maximum (137.33 days) to physiological maturity, followed by Variety Negelle (129.67 days), Huruta (130.33 days), and local check (127.33 days) at Debre Markos (Table 6). The earliness of physiological maturity in location was due to the genotypic effect of varieties and the difference in temperature of growing locations.

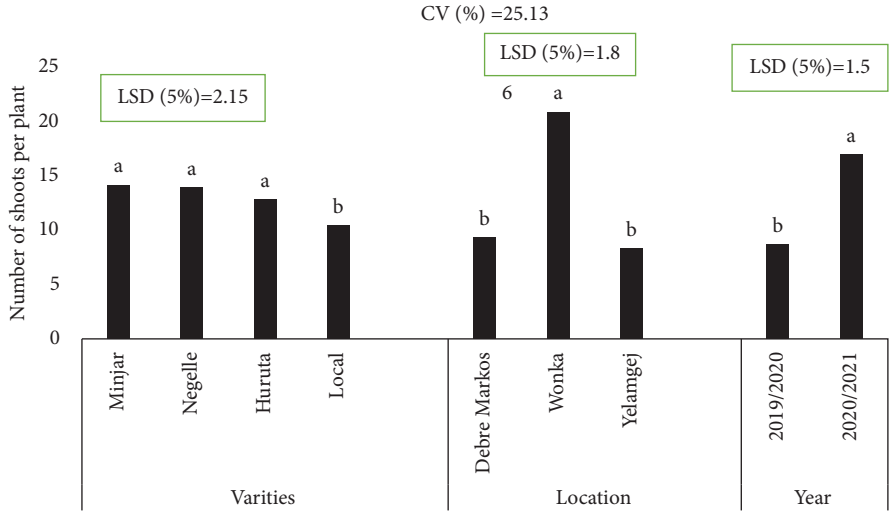

Figure 2: Effects of variety, growing location, and season on number of shoots per plant of shallot.

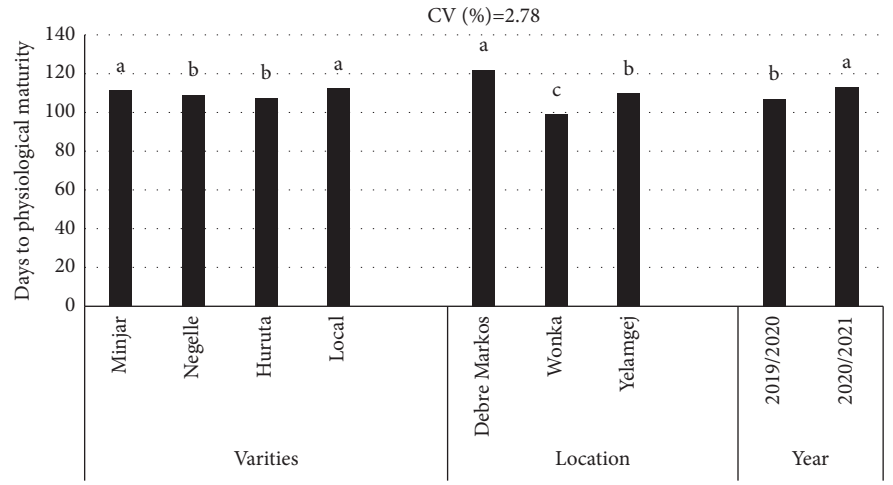

Figure 3: Effects of variety, growing location, and season on days to physiological maturity of shallot.

Table 6: Interaction effect of variety and location on days to physiological maturity of shallot at Debre Markos, Wonka, and Yelam Gej during 2019/2020 and 2020/2021.

Variety	Year					
	2019/2020			2020/2021		
	Debre Markos	Wonka	Yelam Gej	Debre Markos	Wonka	Yelam Gej
Minjar	113.6^{b}	98.66^{de}	113.67^{b}	137.33^{a}	98.66^{fg}	106.33^{de}
Negelle	106.3^{cd}	97.33^{f}	110.00^{bc}	129.67^{b}	100.33^{fg}	110.33^{cd}
Huruta	106.0^{cd}	95.66^{f}	105.67^{cd}	130.33^{b}	95.00^{g}	112.33^{c}
Local	124.0^{a}	103.33^{de}	109.33^{bc}	127.33^{b}	101.00^{ef}	109.67^{cd}
CV (%)	2.765				3.137	
LSD (5%)	3.309				5.816	

Means followed by the same letter(s) within the same column are not significantly different.

Similar results were recorded by Getachew and Asfaw [12] who reported days to maturity of shallot showed variations from 95 days to 126 days. Kimani et al. [28] also detected variations in days to maturity among onion cultivars, and the values are affected by the growing environment.

3.5. Bulb Neck Diameter (cm). Two years of the combined analysis indicated that the main effects of varieties, location, and the interaction of varieties and growing location were significantly ($p < 0.01$) influencing bulb neck diameters (Table 3).

The results indicated that the highest bulb neck diameter of shallot was recorded from variety Minjar (1.46 cm) at the Debre Markos testing site, followed by Negelle, Huruta, and local varieties at the Debre Markos site while the lowest bulb neck diameter was obtained from local check (0.55 cm) at Yelam Gej testing site (Table 7). The significant difference between bulb neck diameters of shallot varieties might be attributed to the genotypic variation and their interaction with growing environment [29].

3.6. Number of Bulblets per Bulb. Number of bulblets per bulb of shallot was very highly significantly ($p < 0.0001$) affected by the main effects of varieties. However, the interaction of varieties, growing environment, and season were not significantly influenced the number of bulblets per bulb of shallot Table 3).

The maximum number of bulblets (7.91) was recorded from the variety Minjar which was statistically similar to Huruta (7.36). The lowest bulblets per bulb were obtained from the local variety (5.73) which is on par with that of Negelle (Table 8). The difference in varieties in bulblet numbers might be due to the differences in their genetic makeup. Similar results were reported by Shimeles [30] and Shimeles and Lemma [26] who reported that varieties of shallot differed in bulblet number in response to growing environments/location. In addition, Shimeles [30] and Tagele et al. [31] indicated that the number of bulblets is a very good measurement of shallot bulb quality and a potential indicator for the identification of shallot lines from a single-bulb onion crop. Tabor et al. [32] also reported that shallots grown from seeds or seedling clusters contain an average of 1–3 bulblets per bulb.

3.7. Average Bulblet Weight (g). The analysis of variance revealed that the average bulblet weight of shallot was highly significantly ($p < 0.001$) influenced by the main effects of varieties, growing location, and season. In addition, the interactions of the location and verities and location by growing season were also highly ($p < 0.001$ affected average bulb weight of shallot (Table 3).

Separate analysis by location showed, at Debre Markos, the largest average bulblet weight was recorded from Variety Minjar (297.00 g), Negelle (257.16 g), and Huruta (239.66 g) while the lowest average bulblet weight (106.1 g) was recorded for local varieties. Similarly, at Wonka Minjar (261.67 g) Negelle (200.00 g) and Huruta (231.67 g) recorded the maximum weight of average bulblets. The lowest average bulblet weight (100.00 g) was recorded from the local variety at Yelam Gej, and the largest average bulblet weight was recorded from Minjar (117.00 g), Negelle (257.16 g), and Huruta (239.66 g) (Table 9) while the lowest average bulblet weight (106.1 g) was recorded for local varieties. Minjar, Negelle, and Huruta had consistently recorded the maximum average bulb let weight in all locations, except Huruta in Yelam Gej.

3.8. Bulb Length (cm). Varieties and growing location revealed a highly significant ($p < 0.001$) effect on the mean bulb length of the shallot plant. However, there is no interaction effect on shallot varieties, growing location, and season (Table 3). The longest bulb length (6.72 cm) was recorded from variety Minjar at Debre Markos; however, it was statistically similar to variety Negelle (6.0708 cm) at Debre Markos and Minjar and Negelle at Wonka and Yelam Gej. However, the shortest bulb length (3.9458 cm) was recorded from the local variety at Wonka, which was statistically similar to the same variety at Debre Markos (Table 10).

This variation of bulb length between varieties and different location might be due to the variation among varieties inherent characteristics and their interaction with the environment. Similar results are reported by Islam et al. [33], who explained significant genotypic variation of bulb length on onion.

3.9. Bulb Diameter (cm). The varieties, growing location, and season showed a highly significant ($p < 0.01$) difference in the bulb diameter. Moreover, the interaction effect of variety with location and varieties with growing season significantly ($p < 0.05$) influence the bulb diameter (Table 3).

The maximum bulb diameter (3.38 cm) was recorded from varieties Minjar and Negelle at Debre Markos, while the lowest bulb diameter was recorded from local check in all growing environments (Table 10). The difference in varieties in bulblet numbers and bulb diameter might be due to the differences in their genetic makeup. Similar results were reported by Shimeles [30]; Shimeles and Lemma [26], Biru [34], Esuyawuka-Moges, and Biruk-Masrie [25] reported that varieties of shallot differed in bulb diameter in response to growing environments/location.

3.10. Average Bulb Weight (kg). There was a highly significant ($p < 0.01$) difference between varieties, growing location, and season on average bulb weight (Table 3). However, the interaction of variety and location were not significantly ($p > 0.05$) affect a bulb weight. The maximum mean bulb weight was obtained from variety Minjar (0.1081 kg) during 2019/2020 and (0.1606 kg) during 2020/2021 while the lowest average bulb weight was recorded from the local variety in both years (Table 11). The difference between the mean weights of bulbs might be due to their genotypic difference. The present result is similar to the findings of Shimeles [30], Shimeles and

Table 7: Effects of varieties on bulb neck diameter (cm) at Debre Markos, Wonka, and Yelam Gej testing locations.

Varieties	Bulb neck diameter		
	Debre Markos	Wonka	Yelam Gej
Minjar	1.46[a]	0.6[cd]	0.62[cd]
Negelle	1.23[b]	0.62[cd]	0.61[cd]
Huruta	1.10[b]	0.64[cd]	0.80[c]
Local	1.10[b]	0.60[cd]	0.55[d]
CV (%)	20.39		
LSD (5%)	0.225		
Significance level	**		

Means followed by the same letter(s) within the same column are not significantly different.

Table 8: Main effect of varieties, growing location, and season on number of bulblets per bulb on shallot plant.

		Number of bulblets per bulb
Varieties	Minjar	7.91[a]
	Negelle	6.40[bc]
	Huruta	7.36[ab]
	Local	5.73[c]
LSD (5%)		0.89
Significance level		***
Location	Debre Markos	6.63
	Wonka	6.83
	Yelam Gej	7.04
LSD (5%)		0.77
Significance level		ns
Season	2019/2020	7.10
	2020/2021	6.56
LSD (5%)		0.63
Significance level		ns
CV (%)	19.61	22.41

Means followed by the same letter(s) within the same column are not significantly different.

Table 9: Average bulblet weight (g) of shallot varieties at three locations (Debre Markos, Wonka, and Yelam Gej) combined by years.

Variety	Average bulblet weight		
	Debre Markos	Wonka	Yelam Gej
Minjar	297.00[a]	261.67[a]	117.0[a]
Negelle	257.16[a]	200.00[a]	86.3[b]
Huruta	239.66[a]	231.67[a]	122.6[a]
Local	106.17[b]	100.00[b]	79.7[b]
CV (%)	17.34470	29.65089	24.05958
LSD (5%)	40.84406	41.39056	14.72602

Means followed by the same letter(s) within the same column are not significantly different.

Lemma [26], and Esuyawkal and Biruk-Masrie [25], who reported the difference in mean fresh bulb weight among varieties. Kokobe and Hirut [35] also reported a significant difference in average bulb weight between onion varieties under the Hawassa condition.

3.11. Total Dry Bulb Yield (t/ha). The analysis of variance showed a significant ($p < 0.05$) difference between varieties, growing location, and season on the dry bulb yield of shallot (Table 3). Moreover, the interaction effects of the three factors were highly significantly ($p < 0.01$) influenced total dry bulb yield. At Debre Markos, the maximum total dry bulb yield was obtained from the variety Minjar (35.9844 t/ha), which was on par with Negelle (27.2185 t/ha) and Huruta (25.5055 t/ha) while the lowest total bulb yield per hectare was obtained from the local variety (18.7122 t/ha) which was statistically similar to that of Negelle and Huruta. At Wonka, the maximum total dry bulb yield was obtained from varieties Minjar (24.88 t/ha[1]), Negelle (23.9630 t/ha), and Huruta (20.7407 t/ha) while the lowest total fruit yield per hectare was obtained from local (12.7778 bt/ha). At Yelam Gej, the maximum total dry bulb yield was obtained from varieties Minjar (14.4601 t/ha), and Huruta (13.5821 t/

Table 10: Interaction effect of variety and location on shallot bulb length (combined over years).

Location	Variety	Bulb length (cm)	Bulb diameter (cm)
Debre Markos	Minjar	6.7208[a]	3.38[a]
	Negelle	6.0708[ab]	3.38[a]
	Huruta	5.3583[bcd]	2.90[b]
	Local	4.6333[de]	2.34[cd]
Wonka	Minjar	0.2881[bcd]	2.45[cd]
	Negelle	5.48833[cd]	2.32[cd]
	Huruta	5.1708[bcd]	2.46[bcd]
	Local	3.9458[e]	2.02[d]
Yelam Gej	Minjar	5.5792[bc]	2.40[cd]
	Negelle	5.3917[bcd]	2.19[cd]
	Huruta	5.6851[bc]	2.52[bc]
	Local	4.9667[cd]	2.14[cd]
CV (%)		12.52	13.44
LSD (5%)		0.222197	0.44
Significance level			**

Means followed by the same letter(s) within the same column are not significantly different.

Table 11: Average bulb weight of shallot varieties during 2019/20 and 2020/21.

Variety	Average bulb weight (kg)	
	Year	
	2019/20	2020/21
Minjar	0.1081[a]	0.1606[a]
Negelle	0.05661[bc]	00.1204[c]
Huruta	0.08447[ab]	0.1353[b]
Local	0.03489[c]	0.1119[c]
CV (%)	20.80509	11.02856
LSD (5%)	0.021652	0.047978

Means followed by the same letter(s) within the same column are not significantly different.

ha), while the lowest total dry bulb yield per hectare was obtained from the variety local (9.7895 t/ha) and Negelle (10.8262 t/ha). The maximum mean combined yield was recorded by varieties Minjar, Negelle, and Huruta at Debre Markos and Wonka, Minjar, and Huruta at Yelem Gej. Minjar was found consistently the highest yield compared to the local check at all locations. Negelle and Huruta were also found to be better. This may indicate that Minjar is a suitable variety over a range of environmental conditions (Table 12).

The maximum yield was obtained from the Minjar variety. This was due to the highest bulblet number per bulb, the highest average bulblet weight, and maximum average bulb weight plant. In addition, this might be because the varieties have different yield potentials as well as genetic and environmental interaction effects. The present result is in agreement with the findings of Shimeles and Lemma [26], and Esuyawkal-Moges and Biruk-Masrie [25] reported significant yield differences among shallot varieties. Shimeles [30] also reported the difference in mean bulb yield of varieties from different locations Zewai, Kulumsa, and Melkassa. Ademe et al. [14], Hailu et al. [24], and Huruta and Minjar gave higher bulb yields and yield components in Aneded Woreda, western Amhara, and Wolaita Zone, Southern Ethiopia. Likewise, Tabor [36] conducted a multilocation trial, and the result showed a significant difference between location and variety. Tesfa et al. [37] also reported that all improved cultivars had higher total bulb yields than the local landrace.

3.12. Marketable and Unmarketable Bulb Yield (t/ha). The analysis of variance for the variety, growing location, season, and their interaction showed a significant ($p < 0.05$) difference in marketable bulb yield (Table 3). Variety Minjar recorded the highest marketable bulb yield (35.1092 t/ha) at the Debre Markos site, which was statistically similar to Negelle (26.0130 t/ha) and Huruta (23.8324 t/ha), while the least total bulb yield per hectare was recorded from a variety local at the Wonka testing site (Table 13). Marketable bulb yield differences between cultivars could be due to genetic differences, which control plant growth and development and indirectly determine bulb size through the amount of carbohydrates synthesized and made available for storage in bulbs. Similar results are recorded by Ademe et al. [14], Hailu et al. [24], Shimeles and Lemma [26], and Esuyawkal and Biruk [25], who reported that the marketable yield difference was due to genotypic difference. Tesfa et al. [37] also reported that all improved cultivars had higher total marketable yields than the local landrace.

Table 12: Effect of variety on total dry bulb yield (t/ha) of shallot grown at three locations over two years.

Variety	Location		
	Debre Markos	Wonka	Yelam Gej
Minjar	35.9844[a]	24.8889[a]	14.4601[a]
Negelle	27.2185[ab]	23.9630[a]	10.8262[b]
Huruta	25.5055[ab]	20.7407[a]	13.5821[a]
Local	18.7122[b]	12.7778[b]	9.7895[b]
CV (%)	27.15490	25.89738	29.84691
LSD (5%)	5.166827	3.458039	2.251644

Means followed by similar letter(s) in a column are statistically similar at 5% significant levels.

Table 13: Mean values of marketable bulb yield (t/ha) and unmarketable bulb yield (t/ha) as affected by varieties at Debre Markos, Wonka, and Yelam Gej locations.

Variety	Marketable yield (t/ha)		
	Debre Markos	Wonka	Yelam Gej
Minjar	35.1092[a]	23.8038[a]	13.8379[a]
Negelle	26.0130[ab]	20.1588[ab]	9.8929[b]
Huruta	23.8324[ab]	23.0254[a]	12.6043[a]
Local	16.9229[b]	11.9187[b]	8.7969[b]
CV (%)	28.71516	23.78326	23.16045
LSD (5%)	5.515269	3.234584	2.343675

Means followed by similar letter(s) in a column are statistically similar at 5% significant levels.

4. Conclusions and Recommendations

The salient findings of the present result indicated that growth, yield, and yield component traits are influenced by the main effects of varieties, growing location, and season. The highest plant height, leaf length, number of shoots per plant, number of bulblets per bulb, average bulb weight, total yield, and marketable yield per hectare were recorded form improved shallot varieties Minjar, Negelle, and Huruta. While local variety is also good in total yield per hectare. However, it is small in bulb length, bulb diameter and marketable yield.

Thus, Minjar, Negelle, and Huruta were found to be superior in yield and yield components at all testing locations and were thus suggested to be used by the growers in the study area. The local cultivar would also have maintained for its yield traits for future breeding improvement activities. Since the study was the first of its kind in the study area, it would be advisable to evaluate the varieties in a participatory varietal trail for further dissemination of varieties to shallot growers.

Data Availability

The data used to support this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

All authors contributed to fieldwork. All authors commented on the existing versions of the manuscript and have read and agreed to the final version of the manuscript.

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