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The effects of intra-row spacing, bulb topping and their reaction on yield and standard of some shallot varieties

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Abstract

Scarcity of improved varieties and production practices have been the bottlenecks of shallot productivity in Amhara region. Bulb topping have been traditionally practiced among shallot growers in the region though its importance remained controversial among interested groups worldwide. There was no recommended spacing for shallot in the study area and farmers used to practice broadcasting. Thus, a field experiment was conducted to investigate intra-row spacing, variety, bulb topping and their interactions influences on yield and quality of shallot and thereby to recommend the optimum practices. The study was undertaken between December 2009 and May 2010 at Gudalima nursery site, Aneded Woreda. Three different intra-row spacings (10, 15 and 20 cm) and two bulb types (whole and topped at one-third of bulb height) were evaluated using four varieties of shallot ('local', 'Negelle', 'Huruta' and 'Minjar') with RCBD replicated three times. Data were recorded and subjected to ANOVA using SAS 9.2 software. The results of the study showed significant varitial, intra-row spacing, two way, and three way interaction effects. Topped bulbs of 'Huruta' planted at 20 cm and 'Minjar' planted at 10 cm intra-row spacings produced the highest and the lowest bulb weight per plant respectively. Topped bulbs of Huruta and Negelle planted at 20 cm intra-row spacing produced the highest marketable yield per ha. Using the topped bulbs of 'Huruta' and 'Negelle' at wider intra-row spacing positively influenced the majority of yield and quality parameters evaluated. Thus, it is advisable to use the 20 cm intra-row spacing and topped bulbs for better production of marketable yield. However, further investigations should be made to come up with complete recommendations.

Keywords: Bulb topping, intra-row spacing, quality, shallot.

INTRODUCTION

Shallot *(Allium cepa* L. Aggregatum group) is a perennial plant produced as annual and produces several bulbs from a single parent bulb (Tindall, 1983; Splittstoesser, 1990; Smartt and Simmonds, 1995; Robinowitch and Kamenetesky, 2002). It is thought to be originated in western Asia where it has been cultivated since very early period. It is being cultivated in Tropical Asia, West Africa, Central and East Africa, Tropical South America and the Caribbean. On a global base, shallot is a minor alliaceous crop. However, in areas where onion seed is hard to produce, or onion production is difficult and the growing season is too short for the production of bulb onion, shallot is cultivated as an important substitute for bulb onion in Southeast Asia, as well as in some African countries including Ethiopia (Robinowitch and Kamenetesky, 2002; Thomas, 2008). Shallot is widely produced in high- and mid- altitudes of Ethiopia and mainly used as condiment (Getachew and Asfaw, 2000; Getachew et al., 2009). According t o BOARD (2002),

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shallot is among the major cash crops produced in Amhara region including the study area, East Gojam Zone. However, production and productivity has been limited due to its propagation using vegetative bulbs, absence of improved varieties, lack of improved production and protection technologies, high post-harvest losses, and absence of vibrant market system that encourages producers (Getachew et al., 2009).

Shallot is planted as topped and whole bulb in different parts of the world. Rashid and Singh (2000) and Robinowitch and Kamenetesky (2002) reported that the growing portion of the bulb is topped one-fourth to one-third of the height for easy and quickly sprouting of more growing buds. Peter (2006) also reported that bulbs are topped to break bud dormancy and enhance uniform sprouting prior to planting. Godfrey-Sam-Agrey et al. (1987) reported that topped bulbs emerge four to five days earlier than whole bulbs. However, Sharma *et al.* (2008) reported that planting of whole onion bulbs produced significantly higher bulb yield (1.57 t per ha more) than one-third topped bulbs. Getachew and Asfaw (2000) also reported that topped medium sized bulbs established significantly lower crop stand and less fresh bulb yield than whole bulbs of the same and large-sized bulbs and attributed to reduced initial food reserve and predisposal of the bulbs to fungal diseases and other decaying organisms. The authors, however, suggested that bulb topping could be practiced under conditions where bulb diseases are not problems. Despite the afore-mentioned research results, farmers in the study area have been practicing topping as one of the indispensable production practices. Thus, there is a need to investigate the contradictory research results and the practice of the farming community in order to recommend the practice for use in major shallot producing areas of the region.

The optimum intra-row spacing is not yet established for Western Amhara. Williams et al. (1991) and Tindall (1983) reported that shallots are commonly planted at intra-row spacings between 12 to 15 cm. Devi and Anal (2008) recommended 10 cm as optimum intra-row spacing for shallot for higher marketable yield. Bodnar (2010) also reported shallots planted at 15 to 20 cm between the bulbs gave highest marketable yield. Thus, internationally, optimum intra-row spacing for shallot is contentious and is dependent on the experience of the production areas. There is no recommended plant spacing for shallot in the study area and farmers traditionally practice non-uniform plant spacing to grow shallots. Some farmers use the intra-row spacing recommended for onion (10 cm) despite the fact that shallots produce multiple bulbs per plant unlike onion and thus need totally different intra-row spacing. Absence of improved shallot varieties in the region also has been a bottleneck to its production and productivity. Hence, the objective of the present study was to investigate the effects of bulb topping, intra-row spacing and their interaction on yield and quality of some shallot varieties in Aneded Woreda, Western Amhara.

MATERIALS AND METHODS

Study site

The study was conducted in 2009/2010 from December 2009 to May 2010 under irrigated condition at Aneded Woreda, Eastern Gojam Zone of western part of Amhara region; 280 km northwest of Addis Ababa, Ethiopia. The experimental site is located at 10° 14'N latitude and 37° 52'E longitude and has an altitude of 2443 m above sea level with average annual rainfall of 1102 mm, the mean maximum and minimum temperature of 23 °C and 10.6 °C, respectively, a soil with a pH of 5.7, percent organic matter of 4.7 and soil texture of silt clay.

Experimental material and treatments

There were 24 treatment combinations, consisting of four varieties (*Negelle*, *Huruta*, *Minjar* and Local), three intra-row spacing (10, 15 and 20 cm) and two bulb types (one-third topped bulbs and whole bulbs). Bulbs were stored at the same condition to maintain uniform resting period. Cured and medium sized (20 to 30 g) bulbs were selected for the experiment. Half of the bulbs from each variety and spacing combinations were topped to one-third of bulb height and the lower two-third of the bulbs were planted, while the remaining half of them were planted as whole bulbs on ridges and with spacing of 30 cm between double rows, 30 cm between rows and 10, 15 and 20 cm between plants based on the treatment combinations (Getachew et al., 2009).

Experimental design

The experiment was laid out in 4*3*2 factorial arrangement using a randomized complete block design with three replications. The size of each experimental plot was 3.6 m^2 (3 m wide and 1.2 m long). The distance between blocks and plots were 1 and 0.5 m, respectively.

Management of the experiment

The treatments received 69 kg/ha N and 92 kg/ha P_2O_5 (Getachew et al., 2009). All the P_2O_5 and half of N fertilizers were applied during planting and the remaining half N was applied after a month of 50% sprouting (BOARD, 2002). Irrigation water was applied for all plots on the day of planting to avoid desiccation on topped bulbs. There was occurrence of downy mildew (*Peronosphora destructor*) and Redomil gold 63.5 was sprayed four times at the rate of 3.0 kg per ha, mixing in 1000 liter water per ha. All other management practices were provided as per the recommendations (Getachew et al., 2009).

Data collected

Data were collected and analyzed for yield and quality parameters evaluated from ten randomly selected plants and the mean was taken except for yield (t/ha) and quality parameters in which the data was recorded on net plot bases.

Weight of bulb per plant (g)

Mean bulb weight of ten sampled plants. It was measured after harvested and cured, using sensitive balance (model BP 16000-s, county in gram and precision 0.01) and expressed in gram.

Weight of marketable bulbs per plant (g)

Mean marketable bulb weight of ten sampled plants. Average weight of healthy matured bulbs greater than 25 mm in diameter (Prissana-nanthakul, 2008) was measured after curing using sensitive balance and expressed in gram.

Weight of unmarketable bulbs weight per plant

Mean unmarketable bulb weight of sampled plants. Average weight of abnormal matured bulbs and less than 25 mm in diameter was measured after curing using sensitive balance and expressed in gram.

Biological yield per plant

Mean biological yield of ten sampled plants. It is the sum total of weight of aerial parts (shoot parts) and under ground parts (bulbs and roots) and was measured after the bulbs were lifted and all the soil was removed and was expressed in grams.

Harvest index per plant (%)

It was computed by dividing mean weight of mature bulb of plants taken (economic yield) by the mean biological yield of plants taken using the equation (Pessarakli, 2001):

$$\text{Harvest Index} = \frac{\text{Economic Yield}}{\text{Biological Yield}} * 100$$

Total yield (t/ha)

Sum total of marketable and unmarketable bulb yield. The total bulb yield (kg/plot) from the net plot was weighed after the bulbs cured for two days under shade, and was converted to t/ha.

Marketable yield (t/ha)

Total weight of clean, disease and damage free bulbs with greater than 25 mm in diameter measured in kg/plot and converted in to t/ha.

Unmarketable yield (t/ha)

Total undersized, defected and diseased bulb weight and expressed in kg/plot and converted in to t/ha.

Bulb dry weight (g)

From each plot, bulbs of sample plants were lifted, 10 bulbs were randomly selected, and fresh weigh was recorded and then cut into pieces, dried in oven at 105°C for 60 h to constant weight. Mean dry weight of bulbs was recorded in gram.

Bulb dry matter content (%)

It was from the ratio of dry weight to fresh weight and expressed in percent as the formula suggested by Undersander et al. (1993).

$$\text{Dry matter content (\%)} = \frac{m_b - m_e}{m_f - m_e} * 100$$

Where: m_b = mass of the dish containing dry matter in grams m_f = mass of the dish containing fresh weight in grams m_e = the mass of the empty dish in grams

Total soluble solids (%)

Total amount of soluble solids present in the bulb. It was recorded from the juice of five randomly sampled bulbs of each plot and was measured using an electrical bench refractometer (Model NAR-1T, made by Wagtech International Limited, Atago digital thermometer) at Debre Zeit Agricultural Research Center horticulture section laboratory at a temperature of 20°C and expressed in percent.

Shape of bulb

The shape of ten randomly selected mature bulbs per plot was classified based on IPGRI descriptors for Alliums species (IPGRI, 2001). The shape index (bulb length to bulb diameter ratio) was used for analysis.

Bulb color

Color of ten randomly selected bulbs from each plot was scored by experts of Debrezeit Agricultural Research Centre. The numbers were assigned as 1 for deep red, 2 for red and 3 for light red to quantify and analyze the data.

Statistical analysis

The mean values of all the aforementioned parameters were subjected to analysis of variance (ANOVA) using the SAS package (SAS, 2002, version 9.2). Least significant difference (LSD) procedure was used to compare differences between treatment means at p=0.05 whenever the treatment effects were significantly different.

RESULTS

As shown in Table 1, interaction effects of variety, intra-row spacing and bulb topping showed a highly significant ($p<0.001$) difference on total bulb weight and weight of marketable bulbs per plant and a significant ($p<0.05$) difference on weight of unmarketable bulbs per plant.

As presented in Figure 1, the varietals effect showed a very highly significant ($p<0.001$) difference on dry matter content. However, none of the main and interaction effects other than variety were significant for the dry matter content. Local variety gave 9, 20 and 21% more dry matter content over Minjar, Negelle and Huruta varieties respectively.

Table 2 indicates interaction effects of variety, intra-row spacing and bulb topping showed a very highly significant ($p<0.001$) difference on biological yield per plant, harvest index per plant and total soluble solid. As a result, whole bulbs of Minjar planted at 20 cm intra-row spacing and whole bulbs of Huruta obtained at 10 cm intra-row

Table 1. Total, marketable and unmarketable bulb weight per plant of shallot as influenced by the interaction of variety, intra-row spacing and bulb topping.

Variety	Spacing (cm)	Bulb topping	Bulb weight (gram per plant)		
			Total	Marketable	Unmarketable
Local	10	Whole	160.04^{mn}	80.58^{m}	79.46^{bc}
		Topped	168.57^{lm}	91.99^{m}	76.56^{c}
	15	Whole	198.97^{ij}	130.77^{jk}	68.20^{d}
		Topped	202.39^{hij}	138.89^{j}	63.50^{e}
	20	Whole	270.75^{b}	193.73^{fg}	77.03^{c}
		Topped	238.64^{de}	170.65^{hi}	67.99^{d}
Negelle	10	Whole	151.55^{n}	111.10^{l}	40.45^{f}
		Topped	169.68^{lm}	137.13^{j}	32.55^{g}
	15	Whole	191.05^{jk}	161.27^{i}	29.78^{gh}
		Topped	211.68^{ghi}	183.80^{gh}	27.89^{h}
	20	Whole	222.68^{fg}	217.33^{ed}	5.35^{kl}
		Topped	277.34^{b}	273.69^{b}	3.65^{l}
Huruta	10	Whole	146.86^{no}	117.94^{kl}	28.92^{gh}
		Topped	180.98^{kl}	157.83^{i}	23.15^{i}
	15	Whole	217.43^{gh}	204.36^{ef}	13.07^{j}
		Topped	234.98^{ef}	223.25^{d}	11.73^{j}
	20	Whole	263.24^{bc}	252.63^{c}	10.61^{j}
		Topped	308.85^{a}	299.48^{a}	9.38^{jk}
Minjar	10	Whole	132.69^{op}	63.60^{n}	69.09^{d}
		Topped	125.65^{p}	59.05^{n}	66.61^{de}
	15	Whole	182.53^{kl}	107.15^{l}	75.38^{c}
		Topped	209.77^{ghi}	127.65^{jk}	82.12^{b}
	20	Whole	252.37^{cd}	161.46^{i}	90.91^{a}
		Topped	223.97^{efg}	133.48^{j}	90.49^{a}
LSD (0.05)			15.81	14.72	4.21
CV (%)			4.67	5.56	5.37

spacing produced the highest and the lowest biological yield per plant respectively.

The effects of intra-row spacing showed very highly significant ($p<0.001$) difference on bulb dry weight and shallot bulbs planted at 20 cm intra-row spacing produced 25.34 and 66.91% more bulb dry weight than bulbs planted at 15 and 10 cm intra-row spacing respectively.

Table 3 indicated that the interaction effects of variety, intra-row spacing and bulb topping showed a significant ($p<0.05$) difference on total yield per hectare and a highly significant ($p<0.01$) difference on marketable and unmarketable yield per hectare.

Interactive effects of variety and bulb topping revealed a significant ($p<0.05$) difference on bulb dry weight per plant.

The interaction effects of variety and intra-row spacing showed a highly significant ($p<0.01$) difference on bulb shape index. As shown in Figure 5, the main effects of variety on bulb skin color was very highly significant ($p<0.001$). As a result Huruta and Negelle varieties had light red color, Local red color and Minjar deep red color.

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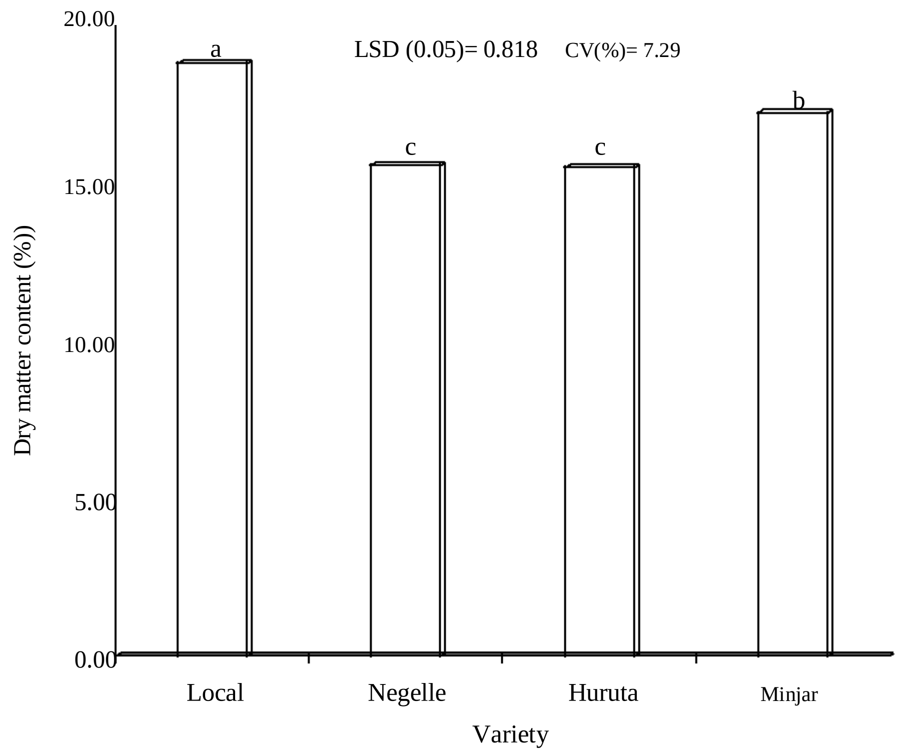

Figure 1. Effects of varieties on percent dry matter content of shallot.

Table 2. Biological yield and harvest index per plant of shallot as influenced by the interaction of variety, intra-row spacing and bulb topping.

Variety	Spacing (cm)	Bulb topping	Biological yield/plant (g)	Harvest index/plant (%)	Total soluble solid (°brix)
		Whole	201.15^{kl}	$79.71\ (8.93^{a-d})$	13.40^{bc}
	10	Topped	214.51^{jk}	$78.60\ (8.87^{a-d})$	13.87^{b}
		Whole	255.22^{i}	$78.28\ (8.84^{a-d})$	15.00^{a}
Local	15	Topped	249.56^{i}	$81.27\ (9.01^{abc})$	13.00^{cd}
		Whole	345.46^{cd}	$78.42\ (8.86^{a-d})$	13.67^{bc}
	20	Topped	284.03^{fg}	$84.01\ (9.16^{a})$	15.17^{a}
		Whole	194.94^{kl}	$77.84\ (8.82^{a-d})$	12.00^{e-h}
	10	Topped	210.93^{jk}	$80.42\ (8.97^{a-d})$	12.33^{def}
		Whole	257.16^{hi}	$74.28\ (8.62^{dc})$	11.07^{i}
Negelle	15	Topped	278.77^{g}	$75.99\ (8.62^{bcd})$	11.23^{hi}
	20	Whole	300.84^{ef}	$74.13\ (8.60^{d})$	11.33^{ghi}
		Topped	363.08^{c}	$76.45\ (8.74^{bcd})$	12.33^{def}
		Whole	184.98^{l}	$79.33\ (8.91^{a-d})$	10.67^{i}
	10	Topped	226.13^{j}	$80.11\ (8.95^{a-d})$	10.83^{i}
Huruta	15	Whole	282.37fg	76.98 (8.77a-d)	11.50f-i
		Topped	287.47fg	82.06 (9.06ab)	12.90cd
	20	Whole	341.65d	77.04 (8.78a-d)	12.17d-g
		Topped	406.13b	76.05 (8.72bcd)	12.17d-g

Table 2. Contd.

	10	Whole	275.95^{gh}	48.20 (6.94^{g})	13.33^{bc}
		Topped	314.20^{e}	40.06 (6.33^{h})	12.35^{de}
Minjar	15	Whole	388.97^{b}	46.94 (6.85^{g})	12.17^{d-g}
		Topped	387.73^{b}	54.13 (7.36^{f})	12.17^{d-g}
	20	Whole	494.41^{a}	50.99 (7.13^{fg})	12.27^{def}
		Topped	340.23^{d}	66.05 (8.11^{e})	12.87^{cd}
LSD (0.05)			6.54	1.272	0.84
CV (%)			5.55	6.20	4.07

Means followed by the same letter in a column are not significantly ($p<0.05$) different, numbers in parenthesis are square root transformations.

Table 3. Total, marketable, and unmarketable yield (t/ha) of shallot as affected by the interaction effect of variety, intra-row spacing and bulb topping.

Variety	Spacing (cm)	Bulb topping	Yield (t/ha)		
			Total	Marketable	Unmarketable
Local	10	Whole	27.54^{ghi}	13.80^{m}	13.74^{a}
		Topped	26.51^{hi}	14.27^{m}	12.24^{b}
	15	Whole	31.65^{e}	20.79^{ij}	10.86^{c}
		Topped	34.63^{cd}	23.63^{fg}	11.00^{c}
	20	Whole	32.56^{de}	23.41^{g}	9.15^{ef}
		Topped	30.48^{ef}	22.15^{ghi}	8.33^{g}
Negelle	10	Whole	31.86^{f}	23.24^{gh}	8.62^{fg}
		Topped	28.28^{fgh}	22.92^{gh}	5.36^{i}
	15	Whole	27.46^{hi}	23.02^{gh}	4.44^{j}
		Topped	36.39^{abc}	32.39^{bc}	4.00^{jk}
	20	Whole	26.37^{hi}	24.00^{fg}	2.37^{l}
		Topped	35.26^{bc}	33.50^{ab}	1.76^{l}
Huruta	10	Whole	31.78^{e}	25.60^{f}	6.18^{h}
		Topped	38.08^{a}	28.56^{e}	9.52^{de}
	15	Whole	35.06^{cd}	29.80^{de}	5.26^{i}
		Topped	37.74^{ab}	32.08^{bc}	5.66^{hi}
	20	Whole	34.72^{cd}	31.25^{de}	3.47^{k}
		Topped	36.21^{abc}	35.48^{a}	0.73^{m}
Minjar	10	Whole	26.52hi	12.55mn	13.97a
		Topped	24.92i	10.97n	13.95a
	15	Whole	30.10efg	16.56l	13.54a
		Topped	34.70dc	21.17hij	13.53a
	20	Whole	28.53fgh	18.40kl	10.13d
		Topped	30.56ef	19.26jk	11.30c

Table 3. Contd.

LSD (0.05)	2.63	2.07	0.68
CV (%)	5.07	5.42	4.98

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

DISCUSSIONS

Total bulb weight per plant (g)

Topped bulbs of '*Huruta'* planted at 20 cm intra-row spacing produced the highest bulb weight per plant followed by the same bulbs of '*Negelle'* planted at similar spacing, whole bulbs of '*Huruta'* planted at 15 cm and whole bulbs of local planted at 20 cm intra-row spacing, whereas both bulb types of '*Minjar'* planted at 10 cm intra-row spacing produced the lowest bulb weight per plant but not statistically different from each other (Table 1). Differences in shallot variety's responses to different intra-row spacings are manifested in differential ability to transform accumulated biomass to bulb production under different intensities of interplant competition. Differences in intra-row spacing enhanced plant-plant variation in terms of accumulated biomass and this phenomenon affected bulb yield and the stability of dry matter partitioning to bulbs. Large plants in wide in-row spacing have competitive advantage and could be identified with high capacity for resource capture and use for bulb production.

This result is consistent with Tendaj (2005) who reported that shallot clusters varied in weight from 50.7 to 342.7 g when shifted from high to low planting density. Kimani et al. (1993) also reported significant bulb yield variation among eight onion cultivars and this variation present among cultivars had different response to factors. Kanton et al. (2003) reported a decrease in bulb weight as the plant population per square meter increased from 50 to 200 plants likely due to competition associated with closely spaced plants that resulted in lower bulb weight per plant. Abubaker (2008) also reported that the highest yield per plant of bean was obtained from 20 and 30 cm spacings as compared to 10 cm. Topped bulbs produced vigorous shoot and owing to optimum space, they would result in bulbs with wider diameter and higher yield. Moreover, better air circulation reduces disease occurrence which contributes to higher yield per plant. Palada and Crossman (1998) also reported that an increase in okra fresh weight per plant from 38 g to 70 g with the increasing in plant spacing from 31 cm to 41 cm due to increasing in the number of stem and wider leaf area per plant at wider spacing. The result is in agreement with Rashid and Singh (2000) who reported that bulb topping should be practiced to enhance vigorous sprouting. In contrast, Getachew and Asfaw (2000) and Sharma et al. (2008) reported topped bulbs produced low yield.

Weight of marketable bulbs per plant (g)

Topped bulbs of '*Huruta'* planted at 20 cm intra-row spacing produced the highest weight of marketable bulbs followed by topped bulbs of '*Negelle'* with the same intra-row spacing, whereas both bulb types of '*Minjar'* planted at 10 cm intra-row spacing produced the lowest weight of marketable bulbs although not significantly different from each other (Table 1). High marketable bulb weight in topped bulbs of '*Huruta'* and '*Negelle'* at wider spacing could be accounted by the production of larger and healthy bulbs at these treatments.

Weight of unmarketable bulbs per plant (g)

Both bulb types of '*Minjar'* planted at 20 cm intra-row spacing produced the highest but statistically similar weight of unmarketable bulbs followed by topped bulbs of '*Minjar'* planted at 15 cm intra-row spacing and whole bulbs of local variety planted at 10 cm intra-row spacing. On the other hand, topped bulbs of '*Negelle'* planted at 20 cm intra-row spacing produced the lowest weight of unmarketable bulbs per plant followed by topped bulbs of '*Huruta'* planted at 20 cm intra-row spacing (Table 1). Production of high unmarketable bulb weight in topped bulbs of '*Minjar'* at wider spacing might attributed to the production of high amount of bolters in these treatments which resulted in small sized bulbs.

Biological yield per plant (g)

Whole bulbs of '*Minjar'* planted at 20 cm intra-row spacing produced the highest biological yield per plant whereas whole bulbs of '*Negelle'* and '*Huruta'* planted at 10 cm intra-row spacing produced the lowest biological yield per plant though they were statistically similar (Table 2). The production of higher biological yield in '*Minjar'* could be because of more flower stalks. Bulbs planted at wider spacing grow more vigorously and obtained more biological yield per plant.

Harvest index per plant (%)

Both bulb types of local, '*Negelle'* and '*Huruta*' varieties planted at all intra-row spacings produced the highest and statistically similar harvest index per plant except both bulb types of '*Negelle'* planted at 15 and 20 cm intra-row spacing and topped bulbs of '*Huruta'* planted at 20 cm intra-row spacing. Whereas, topped bulbs of '*Minjar'* planted at 10 cm intra-row spacing produced the lowest harvest index per plant (Table 2). Higher harvest index was more pronounced in local, '*Huruta'* and '*Negelle'* varieties planted almost at all bulb types and intra-row spacings. This might be, in case of local presence of shorter leaf and plant height and thin leaf diameter will reduced the above ground biomass and resulted in higher harvest index, whereas in case of *'Negelle'* and *'Huruta'*, production of smaller number of leaves and relatively larger bulbs accounted the highest harvest index per plant.

The lower harvest index in '*Minjar'* might be due to the production of more flower stalks which diverted assimilates away from the economically important bulbs. Agele et al. (2007) also reported a significant interaction effect between sun flower varieties and intra-row spacing in terms of total biomass accumulation. Kabir and Sarkar (2008) also reported a significant interaction effect on harvest index of mungbean and the highest value recorded from varieties at closer spacing probably due to the reduced vegetative biomass.

Total yield (t/ha)

Topped bulbs of '*Huruta'* planted at 10 cm intra-row spacing produced the highest yield per hectare but not statistically different from the same variety and bulb type planted at 15 and 20 cm and topped bulbs of '*Negelle'* planted at 15 cm intra-row spacing (Table 3). The higher number of bulbs obtained from *'Huruta'* and *'Negelle'* at higher densities (10 and 15 cm) at harvest compensated for the lower bulb weight associated with higher plant population densities. Whereas, topped bulbs of '*Minjar'* planted at 10 cm intra-row spacing produced the lowest total yield per hectare although it was not statistically different from whole bulbs of the same variety planted at the same spacing and both bulb types of local planted at 10 cm and whole bulbs of '*Negelle'* planted at 15 cm and 20 cm intra-row spacings. Although the narrow spacing produced smaller plants with lower leaf length and diameter per unit area more plants in narrow spacing resulted in higher leaf area index.

Total yield per hectare increased as plant density increased although yield of the individual plants and their components were significantly reduced suggesting a compensation of higher plant densities on yield in shallot. This result is in agreement with Tendaj (2005) 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 to 23.9 t/ha but the majority (86%) of the bulbs are undersized and then unmarketable in case of 5 cm intra-row spacing. Rekowska and Skupien (2007) also observed that significantly higher yield of bulbs and green leaves of garlic was collected when the highest clove planting density in the row has been used (2 cm).

Kanton et al. (2003) also reported onion yield increased from 17.4 to 39.5 t/ha as plant population per square meter increased from 50 to 150. Carlson et al. (2009) reported plant density did impact the yield of two potato varieties and both varieties produced highest total yields at the closest plant spacing 17.75 cm. Hemphill (1987) also reported that a fourfold increase in planting density doubled the yield of shallot. In contrast to the results of the present study, Kabir and Sarkar (2008) 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. Sharma et al. (2008) and Getachew and Asfaw (2000) also reported that planting topped bulbs resulted in reduced yield. As compared with the national average yield of shallot (25.00 t/ha, Getachew et al., 2009), except topped bulbs of *'Minjar'* planted at 10 cm intra-row spacing, all the treatments gave higher yield and *'Huruta'* planted at 10 cm intra-row spacing gave 66% more yield as compared to the yield obtained from improved varieties. This variation might be due to the suitability of the experimental site in terms of soil pH (5.7) and organic matter (4.7%).

Marketable yield (t/ha)

Topped bulbs of '*Huruta'* planted at 20 cm intra-row spacing produced the highest marketable yield per hectare but not statistically different from topped bulbs of '*Negelle'* planted at 20 cm intra-row spacing. On the other hand, both bulbs of '*Minjar'* planted at 10 cm intra-row spacing produced the lowest and statistically similar marketable yield per hectare (Table 3). Production of high amount of marketable yield in topped bulbs of '*Huruta'* and '*Negelle'* at wider spacings might be due to the advantage of producing larger and healthier bulbs per plant on those treatments. This result is in agreement with Tendaj (2005) who reported that an increase in intra-row spacing of shallot from 5 to 20 cm resulted in increase in marketable yield from 21 q/ha to 104 q/ha. Stoffella (1996) also observed that as in-row spacing increased, marketable onion yield increased. Tendaj and Kuzyk (2001) also observed among the intra-row spacings observed (30, 40, 50 and 60 cm) the 40 and 50 cm spacings produced the highest marketable yield of cabbage. Carlson et al. (2009) also reported that the wider spacing of 32.50 cm between plants increased in the production of large sized tubers.

Unmarketable yield (t/ha)

Whole bulbs of '*Minjar'* planted at 10 cm intra-row spacing and produced the highest unmarketable yield per hectare but not statistically different from topped bulbs of '*Minjar'* planted at 10 cm intra-row spacing and both bulb types of '*Minjar'* planted at 15 cm intra-row spacing and

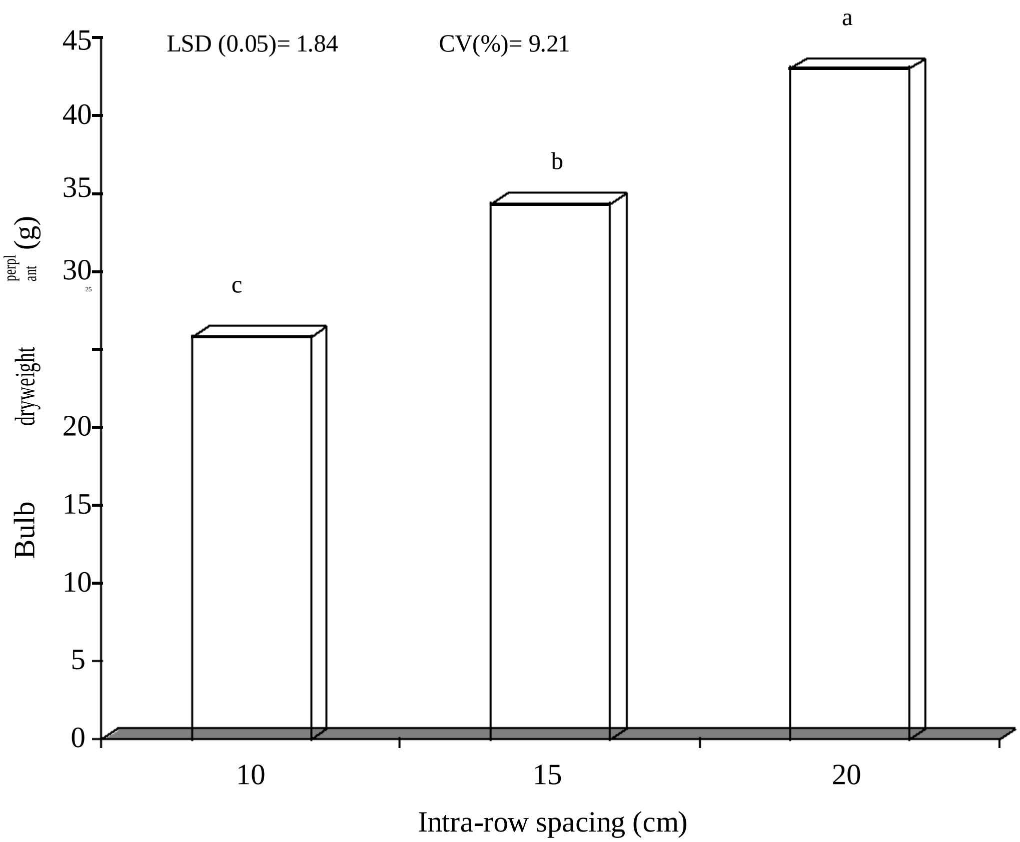

Figure 2. Effect of intra-row spacing on bulb dry weight per plant of shallot.

whole bulbs of local planted at 10 cm intra-row spacing. Whereas, topped bulbs of '*Huruta'* planted at 20 cm intra-row spacing produced the lowest unmarketable yield per hectare followed by topped bulbs of '*Negelle'* planted at 20 cm intra-row spacing and whole bulbs of *'Negelle'* planted at 20 cm intra-row spacing (Table 3). High unmarketable yield in closely spaced plants could be due to inter-plant competition resulted in a fewer large sized bulbs than wider spacings that negatively affected the marketable yield and favored the production of small sized bulbs which are unmarketable. Results of the present study are in consistence with Geremew et al. (2010) who pointed out that unmarketable yield of onion is affected by the interaction between variety and intra-row spacing. The authors observed that Bombey Red planted at 10 cm intra-row spacing produced the highest unmarketable yield (89.87 q/ha).

QUALITY PARAMETERS

Dry matter content (%)

Local variety produced the highest dry matter content followed by '*Minjar*'. The Local variety had 1.56, 3.23 and 3.27% more dry matter than '*Minjar*', '*Negelle'* and '*Huruta'*, respectively which might be attributed to their genetic variation (Figure 1). Kimani et al. (1993) reported a dry matter content variation from low levels of 7 to 10% to high levels of 15 to 20% in onion varieties. The authors further suggested that onions with high dry matter are preferred for processing. They further showed that onions with high dry matter content tend to yield less than those with low dry matter content and the latter also exhibit rapid bulbing.

Bulb dry weight (g)

Bulbs planted at 20 cm intra-row spacing produced greater bulb dry weight per plant than those planted at 15 and 10 cm intra-row spacings. Shallot bulbs planted at 20 cm intra-row spacing had bulb dry weight advantage of 8.7 and 17.25 g over crops planted at 15 and 10 cm intra-row spacings, respectively (Figure 2). The results of this study is in concurrent with Mohammedali (1989) that reported the different in-row spacings had no effect on the dry matter content of onion and so provision of high fresh bulb yields per plant could ultimately lead to high total dry weight production and dehydrated product. Abubaker (2008) also reported that pod dry weight of bean tended to be higher under the lower planting

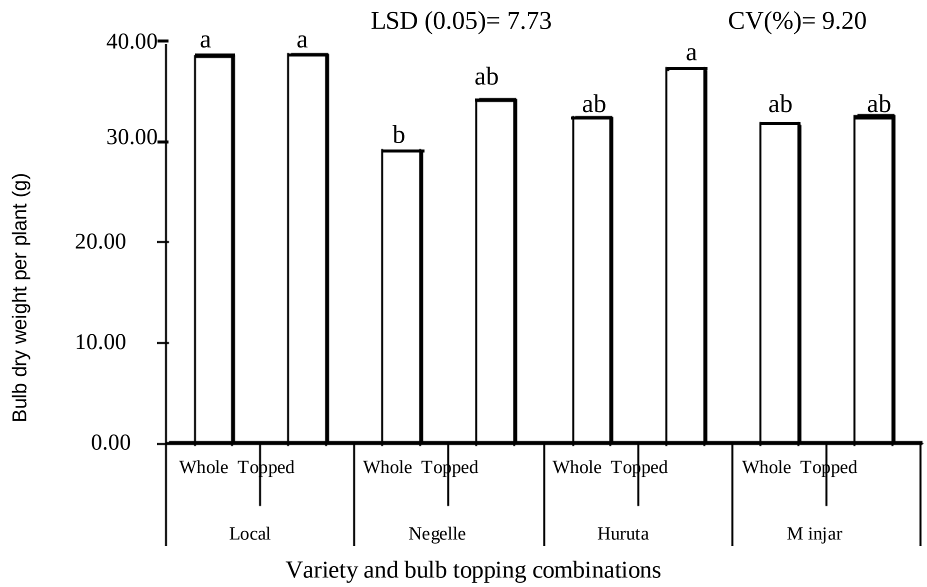

Figure 3. Effects of variety and bulb topping on bulb dry weight per plant of shallot.

densities.

Whole bulbs of '*Negelle'* had the lowest dry weight, but not significantly different form its topped bulbs, whole bulbs of '*Huruta'* and '*Minjar*' (Figure 3). The highly significant positive correlation between bulb dry weight per plant and weight of marketable bulbs per plant (r = 0.68***), total bulb fresh weight per plant (r = 0.90***), and dry matter content (r=0.35**) in the present study also revealed that the presence of higher bulb dry weight per plant is associated with the higher bulb fresh weight (incase of '*Huruta'* and *'Negelle'*) as well as with the higher dry matter content (incase of local and *'Minjar')*.

Total soluble solid (^{0}Brix)

Topped bulbs of Local variety planted at 20 cm intra-row spacing and whole bulbs of the same variety planted at 15 cm intra-row spacing produced the highest total soluble solid. Whereas both bulb types of '*Huruta'* planted at 10 cm intra-row spacing produced the lowest but statistically similar total soluble solid (Table 2). The higher amount of total soluble solid in local and *'Minjar'* might be associated with the presence of small sized bulbs. This result is in consistency with Rajcumar (1997) who reported that a total soluble solid variation of about 4.0 to 16.3% and the maximum was recorded from the local cultivar onion. He further suggested cultivars with high bulb yields have lower total soluble solids content as compared to the cultivars with lowest yields and a negative correlation (r=-0.85) between bulb yield and soluble solids content was found, suggestive of a strong association between these two character. Mallor et al. (2010) also reported significant negative correlation found between bulb weight and soluble solids content. They elaborate these results indicate a trend in larger onions to contain lower rates of both organosulfur derivatives and carbohydrates; therefore, suggesting that bulb size increase was because of higher water content. Walsh et al. (2007) also reported that higher total soluble solid obtained from fruits of plum, peach and nectarine harvested from higher canopy positions with the increase availability of photo assimilates at higher canopy positions due to higher level of irradiation.

Shape of bulb

'*Minjar*' planted at 10 cm intra-row spacing produced a higher bulb shape index (1.61). Whereas '*Huruta*' planted at 15 and 20 cm intra-row spacings produced small bulb shape index (Figure 4). As the bulb shape index become higher, it shows the presence of longer bulb length which result in more cylindrical/oval shape. Crowding plants will produce smaller and slimmer bulbs and longer bulbs harvested at closer spacing because of competition between bulbs and resulted longer bulbs with slim diameter (high bulb shape index). Kimani et al. (1993) reported bulb shape difference among onion cultivars and was affected by environmental conditions. They further explained globe shaped (shape index = 1) are preferred by consumers. Bulb shape and size may also be related to the length of growing period with rapid growth resulting in elongated bulbs while long growing periods produce larger bulbs (Delahaut and Newenhouse, 2003) which was true in the case of '*Minjar'*. The result is also in conformity with the work of Grant and Carter (2010) that pointed out increasing plant density of onion from 50 to 100 plants per square meter increased the percentage of shape rejects due to increased bulb shape index from 7.9

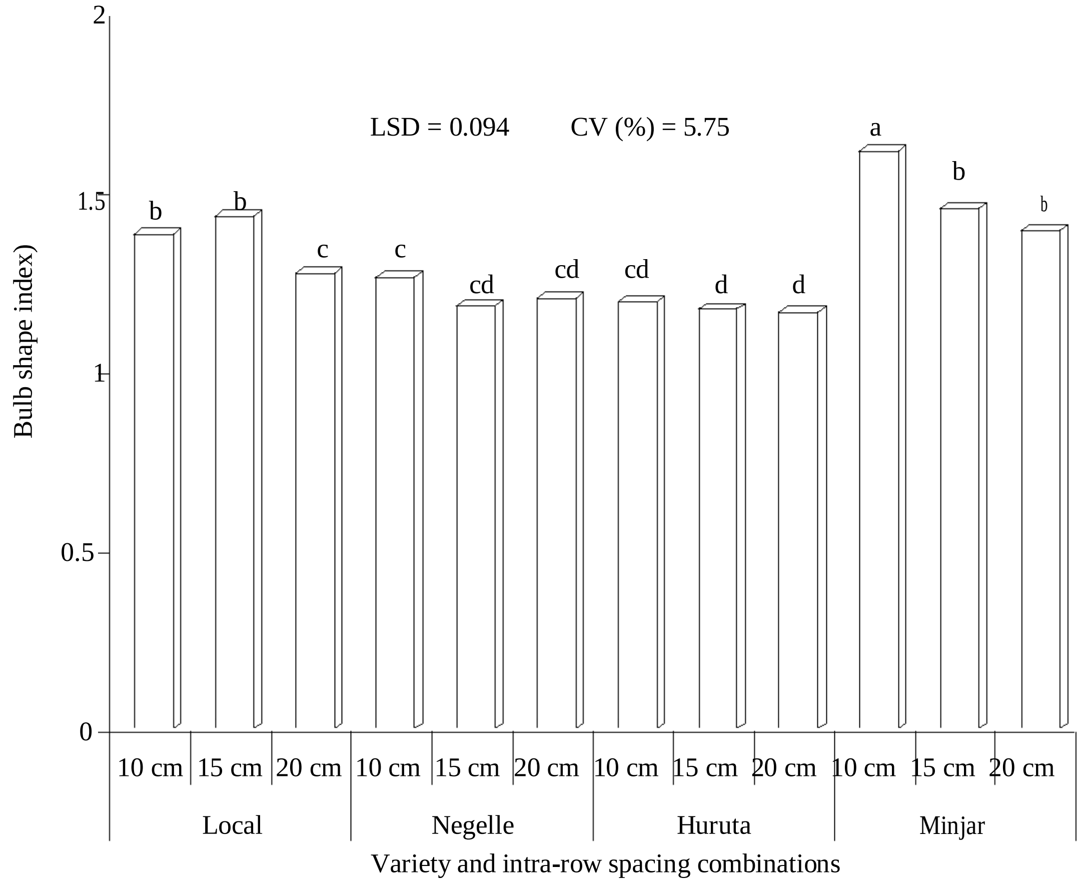

Figure 4. Interaction effect of variety and intra-row spacing on bulb shape index of shallot.

to 15.3%. According to the authors, bulbs having a shape index of >1.2 were regarded as having an unacceptable as European markets demand a flattened globe shaped onion for ease of packaging. Kanton et al. (2003) also reported the increase in bulb shape index of onion with increasing in plant population.

Bulb color

'*Minjar*' produced deep red bulb skin color followed by the local variety that produced red bulb skin colour (Figure 5). *'Negelle'* and '*Huruta'* produced similar light red bulb skin color. The red and deep red skin color bulbs are more demanded by the consumers in the market. This result is substantiating Getachew and Asfaw (2000) who reported bulb shape and skin colour variations were observed among the Ethiopian shallot cultivars.

SUMMARY AND CONCLUSIONS

Shallot is one of the popular and the most cultivated vegetables in Ethiopia in general and in Amhara region in particular. Farmers in the study area produce shallot as a cash crop using topped bulbs of local varieties with non-uniform plant spacing based on the existing indigenous knowledge. The present study was thus conducted to investigate the effect of different intra-row spacings and bulb topping on yield and yield components of four 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, bulb topping and varieties as well as their interactions had substantial influences on different parameters.

The present study showed that planting topped bulbs of '*Huruta'* and '*Negelle'* at 20 cm intra-row spacing had positively influenced the majority of yield and parameters evaluated and thus it is advisable to use these for the production of bigger bulbs with desirable bulb shape index and higher marketable yield. In addition, it is also advisable to use local variety for high dry matter content, total soluble solid, and better bulb skin color. However, production of '*Minjar'* is not advisable in areas having similar conditions with the study area because of its high bolting nature and the consequent yield reduction though it had the best bulb skin color, dry matter content, and total soluble solid unless there is inhibition of the flower stalk production using different cultural practices. 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. In addition, it is better to assess the potential of '*Minjar*' for botanical seed production as it has high bolting nature. This would be a prospect to solve the problems in shallot production expansion by alleviating

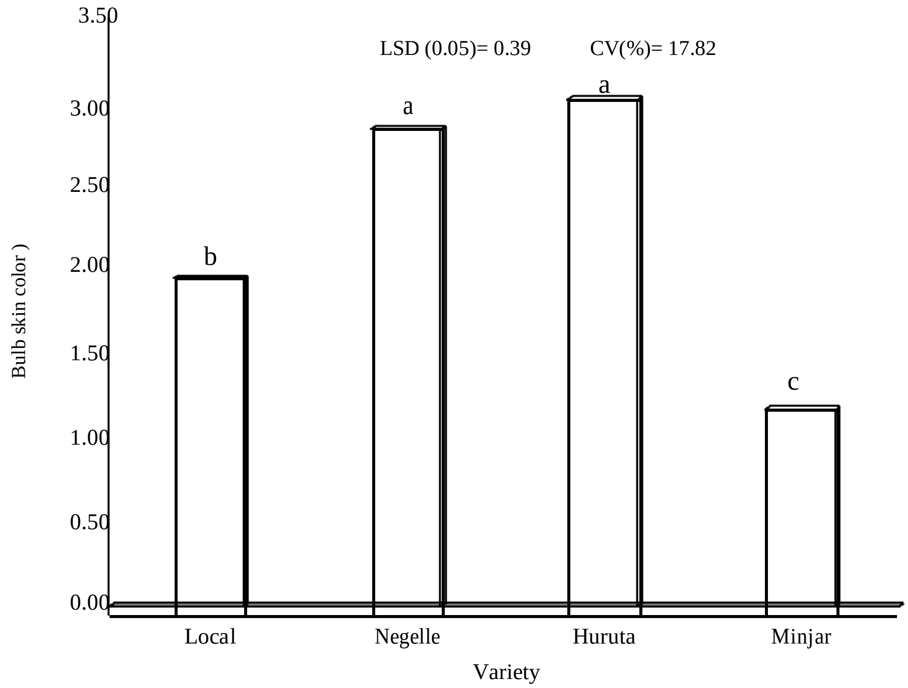

Figure 5. Effects of variety on bulb skin color of shallot.

the shortcomings of using bulbs as a planting material; large quantity, bulkiness, short shelf-life, and source of inoculum for diseases and pests.

REFERENCES

Abubaker S (2008). Effect of plant density on flowering date, yield and quality attribute of Bush Beans (*Phaseolus Vulgaris* L.) under Center Pivot Irrigation System. Am. J. Agric. Biol. Sci., 3(4): 666-668.

Agele SO, Maraiyesa IO, Adeniji I (2007). Effects of variety and row spacing on radiation interception, partitioning of dry matter and seed set efficiency in late season sunflower (*Helianthus annuus* L.) in a humid zone of Nigeria. Afr. J. Agric. Res., 2(3): 080-088.

Bodnar J (2010). Fact sheet: Shallots: What They are and How to Grow Them. Ministry of agriculture food and rural affairs, Ontario. Queen's printer for Ontario: ISSN 1198-712x.

Bureau of Agriculture and Rural Development (BOARD) (2002). Coffee, fruit and vegetables production package (Amharic). Amhara National Regional State, Bureau of Agriculture and Rural Development, Bahir Dar., p. 107.

Carlson LH, Kirby D, Kliewer B, Thompson C (2009). Evaluation of cultural practices to control hollow heart in premier russet**.** University of California Intermountain Research and Extension Center, Research Progress No 121.

Delahaut KA, Newenhouse AC (2003). Growing onions, Garlic, Leeks and other Alliums in Wisconsin: A guide for fresh market growers (A3785). University of Wisconsin- system Board of Regents and University of Wisconsin-Extension, Cooperative Extension.

Devi AK, Anal L (2008). Yield and economic response of multiplier onion (*Allium cepa* L. var *aggregatium* Don.) to agronomic management under Manipur condition. J. Environ. Ecol., 26(4): 44-48.

Grant DG, Carter BV (2010). The influence of cultural factors on the bulb shape of the onion (*Allium cepa* L.) Cultivar "pukekohe longkeeper". ISHS Acta Horticulturae 433: I International Symposium on Edible Alliaceae.

Geremew A, Teshome A, Kasaye T, Amenti C (2010). Effect of intra-row spacing on yield of three onion (*Allium cepa* L.) varieties at Adami Tulu Agricultural Research Centre (mid rift valley of Ethiopia). J. Hortic. For., 2(1): 007-011.

Getachew T, Asfaw Z (2000). Research achievements in garlic and shallot. EARO, Addis Abeba, Ethiopia. Research Report No. 36.

Getachew T, Eshetu D, Tebikew D (2009). Shallot and Garlic Production Guide (Amaharic). Ethiopia Institute of Agriculture Research, Debre Zeite, p. 52.

Godfrey-Sam-Agrey W, Chemedo A, Habtye S (1987). Review of shallot research in Ethiopia and proposals for future research and development directions. In: Godfrey-Sam-Agrey and Bereke Teshay (Eds) proceedings of the first Ethiopian Horticultural workshop. Addis Ababa, Ethiopia. 20-22 February 1985. Institute of Agricultural Research, Addis Ababa, pp. 187-89.

Hemphill D (1987). Over wintering onions and other Allium in the Willamette Valley. Oregon Agric. Exper. Station Special Rep., 794: 44.

IPGRI (2001). Descriptors for Allium (*Allium* spp.). International Plant Genetic Resources Institute, Rome, Italy; European Cooperative Programme for Crop Genetic Resources Networks (ECP/GR), Asian Vegetable Research and Development Center, Taiwan.

Kabir MH, Sarkar MAR (2008). Seed yield of mung bean as affected by variety and plant spacing in *Kharif*-I season. J. Bangladesh Agric. Univ., 6(2): 239–244.

Kanton RA, Abbey L, Hilla RG, Tabil MA, Jan ND (2003). Density affects plant development and yield of bulb onion (*Allium cepa* L.) in Northern Ghana. J. Veg. Crop Prod., 8(2): 15- 25.

Kimani PM, Karinki JW, Peters R, Rabinowitch HD (1993). Influence of environment on the performance of some onion cultivars in Kenya. Afr. Crop Sci. J., 1(1): 15-23.

Mallor C, Balcells M, Mallor F, Sales E (2010). Genetic variation for bulb

.

size, soluble solids content and pungency in the Spanish sweet onion variety Fuentes de Ebro response to selection for low pungency. Blackwell Verlag GmbH. doi:10.1111/j.1439-0523.2009.01737.x.

Mohammedali GH (1989). Effect of plant population densities on yield and quality of white dehydration onion in the Northern Sudan. Hudeiba Research Station, Crop Husbandry Comm., Agric. Res. Corp.,Ed-Damer, Sudan, pp. 213-219.

Palada CM, Crossman MA (1998). Planting density affects growth and yield of Okra. Proceedings of the 34th Annual Meeting 1998- Carrabean Food Crop Society, pp. 52-57.

Pessarakli M (2001). Handbook of crop and plant physiology. Second ed. Marcel Dekker, inc., p. 927.

Peter KV (2006). Handbook of herbs and spices Volume 3. Woodhead Publishing Limited, p. 385.

Prissana-nanthakul S (2008). Notification of the national committee on agricultural commodity and food standards. Subject: Thai agricultural commodity and food standard: shallot BE, 2551: 13.

Rajcumar R (1997). Selection of onion cultivars for yield, early maturity and storage potential in Mauritius. Food and Agric. Res. Council, Reduit, Mauritius, pp. 153-159.

Rashid MA, Singh DP (2000). A Manual on Vegetable Seed Production in Bangladesh: 1st ed, AVRDC-USAID-Bangladesh Project- Horticulture Research Centre, Bangladesh Agricultural Research Institute Joydebpur, Gazipur 70, BANGLADESH, p. 117.

Rekowska E, and Skupien K (2007). Influence of flat covers and sowing density on yield and chemical composition of garlic cultivated for bundle-harvest. pp. 17-24. In: Kosson R., Szwejda J and Górecka K (eds). Vegetable Crops Research Bulletin 66/2007. Research Institute of Vegetable Crops. http://www.inwarz.skierniewice.pl/download.php?fn=66_2007

Robinowitch HD and Kamenetesky R (2002). Shallot (*Allium cepa,* Aggregatum group). pp. 409-430. In: Currah L and Rabinowitch HD (eds.). *Alluim* Crop Science: Recent Advance. CABI, Oxon OX10 8DE, UK,

Sharma PK, |Kumar S, Yadav G and Verma R (2008). Effect of bulb size, cut and uncut bulbs under various levels of nitrogen on growth and seed yield of onion (*Allium cepa*). J. Res. Crops, 9(1): 103-105.

Smartt J, Simmonds NW (1995). Evolution of Crop Plants, 2nd ed. Longman Singapore, p. 348.

Splittstoesser WE (1990). Vegetable Growing Hand Book: Organic tradition method, 2nd ed. Chapman and Hall, New York, pp. 250-253.

Stoffella PJ (1996). Plant arrangement and density of transplants influence on sweet Spanish onion yield and bulb size. Hortic. Sci., 31:129-130.

Tendaj M (2005). Shallot production and research in Polland. pp. 55-60. In: Kosson R, Szwejda J and Górecka K (eds). Vegetable Crops Research Bulletin 62/2005. Research institute of vegetable crops. http://www.inwarz.skierniewice.pl/download.php?fn=62_2005.

Tendaj M, Kuzyk K (2001). Effect of plant density on yielding of red cabbage. Vegetable Crops Res. Bull., 54(2): 35-39.

Thomas SC (2008). Fruits and vegetables: Nutritional and Therapeutic Values. Taylor & Francis Group, LLC, p. 76.

Tindall HD (1983). Vegetables in the tropics. Macmillan Education, pp. 17-20.

Undersander D, Mertens DR and Thiex N (1993). Forage analysis procedures. National forage testing association. Omaha. p. 38.

Walsh BK, Long RL, Middleton SG (2007). Use of near infra-red spectroscopy in evaluation of source-sink manipulation to increase the soluble sugar content of stone fruit. J. Hortic. Sci. Biotecnol., 82(2): 316-322.

Williams CN, Ozo JO, Peregrine WTH (1991). Vegetable production in the tropics. Longman UK. Intermediate Tropical Agricultural Series, p. 144.