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Research Article

Influence of Inter-row Spacing of Carrot (Daucus *carota* var. sativa) Variety under the Irrigated Condition on Seed Yield and quality in Arsi Zone, Ethiopia

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ABSTRACT

Development of recommendation on appropriate plant spacing is one of the important agronomic practices to increase the productivity of carrot. Therefore, a field experiment was conducted to assess the response of carrot variety AU-18 to different inter- row spacing in 2018 and 2019 using irrigation. Three inter-rows spacing of 50, 75 and 100cm were studied keeping 50cm intra-row spacing constant to all treatments. The experiment was carried out using a randomized complete block design (RCBD) with four replications. The results revealed that inter-row spacing showed significant effects ($p<0.05$) on most of measured parameters except days to 50% flowering, number of primary branches per plant, seed yield per primary umbel and seed yield per plant. Accordingly, the highest umbel size (diameter) 9.309cm, number of seed per umbel (2612.4), seed yield per plant (94.21g), seed yield per hectare (1574.1 kg) and 1000 seed weight 91.83g) was obtained at 75 cm inter-row spacing followed by 50 cm inter-row spacing. Seed yield was observed to decline with increased spacing beyond 75 cm inter-row spacing. Seed yield per plant significantly (r = 0.5206*) correlated with number of branches per plant, umbel diameter (r = 0.59268*), number of umbels per plant (r = 0.576*), number of seed per plant (r = 0.3278*) and with thousand seed weight (r = 0.6454*). Thus, based on the results of this experiment, the optimum inter-row spacing for growing carrot variety AU-18 for high seed yield and quality is 75cm x 50cm which corresponds to planting density of 26666 stecklings or plants per hectare (equivalent to 3 plants m-^{2}) in the study area as well as similar agro-ecologies in the country.

Key words: AUA-108, Inter-row spacing, Seed yield, stecklings, Umbel.

INTRODUCTION

Carrot (*Daucus carota* L.) is produced in a wide range of agro-ecologies from the lowlands to the highlands of Ethiopia. It is grown from true seeds and its successful production is dependent upon a sustainable and satisfactory supply of good quality seed (McDonald and Copeland, 1998; Lemma, 1998). Experiences in Ethiopia have indicated that there are places in the country with optimum temperatures for seed production of carrot (Dawit *et al.,* 2004). However, there are only few pocket areas are available for carrot seed production in the country and hence, the majority of the demands for carrot seed is depend on imported seed from abroad. Due to small scale production and low quality of carrot seed produced in Ethiopia, a large quantity of the seed accessible in the market is imported from other countries.

The small seed production and poor quality can be attributed to lack of optimized seed production technology of vegetable crops, starting from seed planting to harvesting and postharvest treatment of seed (Ziaf *et al.*, 2017). Thus, to improve the production and productivity of carrot domestically, the availability of quality seed is crucial (Dawit *et al.*, 2004). Besides various factors, production of good quality carrot seed is highly affected by planting density. Optimum spacing between plants play crucial role in the yield and seed quality of carrot (Kumar *et al.,* 2017) as optimized plant spacing is of prime importance to proliferate the biomass production and nutritional availability to plants and ultimately affect the seed quality (Horbe *et al.*, 2016, Kang *et al.*, 2015). Besides, it helps to avoid shading effect on plants as well as competition for soil moisture, nutrient elements among the plants light and water while enabling efficient use of available of land resources (Chhetri *et al.*, 2019).

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Carrot seed production technology is barely available in the country and although thre area a recommendation for growing good quality carrot seed crop globally, it is not advisable to use general recommendations applicable to the different agro-ecological zones as it could be affected by type of variety, climate and various edaphic factors. Hence, this study was conducted to find out the most suitable inter-row spacing for production of high yield and good quality carrot seed for Arsi highlands of Ethiopia.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at Kulumsa Agricultural Research Center (KARC) which is located at 8°00‟ to 8o02‟N and 39°07‟ to 39°10‟E and an altitude of 2210m a.s.l. in Oromia, Ethiopia. KARC has a low relief difference with altitude ranging from 1980 to 2230 m. The agro- climatic condition of the area is wet with 811mm mean annual rain fall and it is a uni- modal rainfall pattern with extended rainy season from March to September. However, the peak rainy season is from July to August. The mean annual maximum and minimum temperatures are 23.1 and 9.9°C, respectively. The coldest month is December whereas; May is the hottest month (Abayneh *et al.*, 2003).

Experimental planting material and field management

The present study was conducted using one of the renowned open pollinated carrot variety known by the name Haramaya 1 or AUA-108, which was developed by Haramaya University in 2014. The most practiced method (root-to-seed) was used for the study (Organic Seed Alliance, 2018). Carrot seeds were sown in June to produce mature roots (“stecklings”) on well prepared seed beds in the nursery at a rate of 6 kg/ha. Stecklings were harvested in early September and the best characteristic of the variety were selected and then transplanted into a seed production experimental field in mid-September to expose plants to low temperature between October and November. The stecklings were irrigated every 2-3 days to avoid water lose and wilting for good seed crop establishment. The subsequent irrigation water applications intervals were extended to 5 days depending on the establishment and growth of plants as well as weather conditions. Weeding was practiced by hoeing and hand weeding whenever necessary until the crop covered the ground completely. About 175 kg DAP ha^{-1} at transplanting, was applied as the recommended rate for root production of fresh market carrots and Urea (100 $kgha^{-1}$) was top dressed to enhance vegetative growth.

Harvesting of the carrot seeds was started as they turned into dark brown color. The matured umbels were harvested from each plot at different time as carrots have distinct order of flowering and maturity depending on umbel position. The king or primary umbel is the first to flower and ripen followed by secondary and tertiary umbels. Umbels were kept under partial sun and seeds were extracted by hand threshing and winnowing. The seeds were then dried, cleaned very carefully, and weighed for different data purpose.

Treatments and experimental Design

The experiment studied three inter- row spacing (100cm×50cm; 75cm×50cm; 50cm×50 cm) which was laid out in a completely randomized block design with four replications. The plot size measured $12m^2$ (3mx4m), each planted with different number of stecklings (24, 32 and 48 per plot) depending on the three inter-row spacing treatments which corresponded to three plant densities of 20000, 26666 and 40000 plants per hectare respectively.

Data collection and measurement

Days to flowering: The number of days from the date of transplanting to when 50% of the plants in the central rows open flowers on the primary umbel.

Days to fruit set: The number of days from the date of transplanting to when 50% of the plants in the central rows set fruit on the primary umbel.

Plant height (cm): was measured when the first umbel turned to brown. The height was measured from the ground level to the tip of the tallest seed-stalk and the average height of the five plants was calculated for statistical data analysis.

Number of primary umbels per plant: All primary umbels produced by plant in the net plot were counted at harvesting time divided by the number of plants harvested and the average was considered as the number of primary umbels per plant.

Number of primary branch per plant: five randomly taken plants from center rows were counted the number of primary branches at harvesting time, divided by the number of plants harvested and the average was considered as the number of primary umbels per plant.

Primary umbel diameter (cm): The primary umbels produced by five randomly taken then measured umbel diameters from each samples.

Number of seed per primary branch: The primary umbels produced by five randomly taken plants from the central rows were detached, threshed after dried, threshed and divided by the number of primary umbels.

Seed yield of primary umbels (g): The primary umbel produced by five randomly taken plants from the central rows was detached by pruning shear. All sample primary umbels were threshed after drying in the sun and divided by the number of umbels.

Seed yield per plant (g): All umbels produced by plants in the net plot was detached at time of harvesting, kept in the sun, threshed, weighed and divided by the number of plants harvested.

Seed yield per hectare (kg): All umbels produced by plants in the net plot was detached at a time of harvesting, kept in the sun, threshed, weighed by the analytical balance in gram and yield of seed per hectare was calculated from seed yield per plot for each plot.

Thousand seed weight (g): Sample of seeds from the bulk in each plot was taken and 1000 seeds were counted in seed counter machine and weighed using a sensitive balance.

Data analysis

The collected data were subjected to Analysis of Variance (ANOVA) using statistical analysis Software (SAS ve2rsion 9.2, 2009). The mean separation was done using (LSD) test at 5% probability level and simple correlation was made to determine association of parameters by using Pearson analysis.

RESULTS AND DISCUSSION

Phenology and Growth parameters

Days to 50% flowering and head set

Plant population was not significant (p>0.05) on days to flowering and fruit set and hence, days to flowering and head set at closer spacing (high plant density) was not significantly different from that of the wider spacing (low plant density) (Table 1). However, a decreasing trend was observed in days to flowering and fruit set with decreased planting density. This could be due to the effect of competition among plants for some growth resources, such as nutrients, moisture, light etc. On the contrary decreasing planting density appeared to shortened days to flowering and head set. Accordingly, plants at low density (100cm x 50cm) were observed to seed set few days earlier than plants at high planting density (50cmx50cm). We also observed significant differences between years on some of the parameters obviously due to differences in weather conditions between the years. Our finding agrees with the reports of George (1999), who suggested that higher plant densities could shorten the overall flowering period and increased the evenness in umbel ripening. This may be due to the fact that higher plant densities considerably reduce the development of higher order umbels, letting a concentration of umbels to be produced in the upper part of individual plant stalk.

Plant height (cm)

Plant height of carrot seed under spacing was varied significantly (P<0.05) due to spacing. Among spacing treatments maximum plant height 149.26 cm was observed when the crop was planted on inter-row spacing of (100 cm x 50 cm) followed by (75cm x 50 cm), while the shortest plant height plant height was recorded with (50 cm 50 cm). The year also shows highly significant influences on the carrot plant height (Table 1). The greatest plant height may be due to the availability of free access of environmental resources (water, nutrient and light) for the plants in the wider plants. In line with this result, Anam *et al.,* (2020) reported that plant height of carrot plants was significantly affected by spacing of cultivars.

Number of primary branch per plant

Number of primary branch per plant was no significantly (P>0.05) varied in response to inter-row spacing. The mean highest was recorded from the wider spacing (100 cm x 50cm) as compared to the closer spacing (50 cm x50 cm). Increased number of branches per plant in widely spaced plants than in closely spaced ones, for the reason that there is reduced competition for space, nutrients, light and air between the plants between the wider spacing. Earlier reports by Mengistu and Yamoah (2010) showed that, Plants at lower population density (133 333 plants/ha) gave the highest number of secondary and tertiary umbels (7 and 10 respectively) and their number decreased with increasing planting density. In the present study, at lower population density of 100cmx75cm (20000 plants/ha), the highest number of primary branch/plant (8.981) was recorded and it tended to decrease to 8.475 and then to 6.625 when plant population increased to 75cmx50cm (25000 plants/ha) and 50cmx50cm (48000 plants/ha) respectively. This could likely be related with the number of branches extending from the main stalk and the primary branches, at the terminus of which umbels of the respective orders may be formed. The non-significant effect of spacing on number of primary branches per plant could be due to the fact that the planting densities used in the study might be below the level to create significant differences. Norman (1992) reported that increasing plant density does not affect individual plants if the plant density is below the level at which competition occurs between plants.

Number of Umbel on Primary branch per plant

The mean number of umbel on primary branch was significantly (*P*<0.05) influenced by inter- row spacing. The maximum number of umbels per plant on primary branch was recorded with wider spacing 100 cm 50 cm (19.45) which was statistically at par with 75 cm x50 cm spacing, when the data was pooled for both years while minimum number of umbel was recorded with spacing 50cm x 50 cm (12.55) Table-1. There was an increasing trend in number of primary umbels per plant when planting populations decreased in given area. Ahmad and Tanki (1997) observed wider spacing (60 x 60 cm) resulted in more number of umbels, higher umbel weight and better umbel size.

Umbel diameter on primary branch

The application of different inter-row spacing had highly significant (P<0.05) influence on diameter of primary umbels. The mean highest primary umbel diameter (9.309) was recorded for plants that were grown at 75cm × 50 cm row spacing followed by 100 × 50 cm (9.251cm) which were statistically similar with the former. While the lowest umbel diameter (7.983cm) was from 50cm x50cm with significant difference from others treatments (Table 1). At wider spacing (low population density), plants have minimal competition among them for the available resources that could affect growth, development and ultimately the yield, in this case umbel size. The larger the umbel size (diameter), the higher the chance it contains more number of seeds in it and increase yield. Mazumder *et al*. (2007) stated that plants grown under optimum population density per unit area provides optimum conditions for luxuriant crop growth and better plant canopy area due to maximum light interception, photosynthetic activity, assimilation and accumulation of more photosynthates into plant system and hence they produce more seed yield with best quality traits.

Seed yield and yield components

Number of seed per primary branch: The number of seeds per primary branch was significantly (*P*<0.05) affected by the inter-row spacing. The mean highest number of seeds per primary branch (2612.4) was recorded for plants that were grown at 75 × 50 cm (2571.6) row spacing followed by 50cm×50cm (2133.3) spacing (Table 2). This result is positively correlated with what was obtained in umbel size already discussed above (Table 1).

The wider the spacing, the larger umbel size and the more number of seeds per umbel.

Seed yield per primary Umbel (g)

In carrot, umbels of different orders vary in number, size and seed weight. Seed weight depends upon the umbel order; for the primary umbel, there was a non-significant difference ($p<0.05$) in seed yield between the row spacing, while the mean pooled yield of the year shows significant difference. Regardless of the non-significant seed yield differences between the spacing treatments, the highest seed yield per umbel (5.45g) was obtained from 75cmx50cm spacing followed by 100cmx50cm (4.9238g) and 50cmx50cm (4.7075g). Likewise, this result correlates positively with that of umbel size (Table 1) and number of seed per umbel (Table 2). Similarly, increasing planting density considerably reduced the mean seed weight per umbel of each order (Mengistu and Yamoah, 2010), which could be due to the decreasing number of seeds/umbel and umbel size with increasing planting density.

Seed yield per plant (g)

Data procured for seed yield per plant was subjected to statistical analysis which elucidated that they did not significantly ($P<0.05$) differ between row spacing with each other. Nevertheless, the mean highest seed yield per plant (94.21 g) was recorded from plants at 75cm x 50cm followed by 82.3g (50cm x 50cm) and 80.94g (100cm x 50cm). Similar results were reported by Mengistu and Yamouh, 2010 as increased seed weight per umbel with increased plant spacing. This could be due to less effect of competition among plants for growth resources, and also Muhammad and Muhammad (2002) explained the increased seed yield per plant with increasing plant-to-plant distance. However, the planting densities tested in the present study did not create competition to the level needed to affect seed yield per plant. Norman (1992) reported that increasing plant density does not affect individual plants if the plant density is below the level at which competition occurs between plants.

Table 1: Effects of inter-row spacing on phenology and growth parameters of carrot for seed production at Kulumsa, during 2018 to 2019 at irrigation condition

Treatment (Inter-row Spacing)	Days to 50% flowering	Days to fruit set	Plant height (cm)	Number of primary branch per plant	Number of Umbel on Primary branch per plant	Umbel diameter (cm)
Inter-row Spacing						
50 cm × 50 cm	65.83a	94.33a	128.77b	6.625	12.55b	7.983b
75cm × 50 cm	66.80a	91.45b	147.55a	8. 475	16.65ab	9.309a
100 cm× 50cm	64.00a	91.58b	149.26a	8. 981	19.45a	9.251a
Mean	65.543	92.453	141.86	6.625	16.217	8.847
LSD	3.00	1.7	13.483	3.1716	4.549	0.8186
CV (%)	11.20	3.60	9.22	37.45	26.59	8.77
significance	Ns	*	*	Ns	*	**
Year						
2018	66.083	92.9167	117.512b	10.854a	20.267a	9.7625a
2019	65.45	93.00	159.545a	5.2b	12.167b	7.933b
Mean	65.7665	92.9584	138.5285	8.027	16.217	8.84775
LSD	3.0666	2.006	11.009	2.5896	3.7143	0.6684
CV (%)	11.33	1.705	9.226397	37.45513	26.5916	8.770914
Significance	Ns	Ns	**	**	**	*

Means in the same column followed by the same letters are not significantly different at 5% level of significance according to Duncan's Multiple Range Test. ns=non-significant, LSD (5%)=Least significant difference at P=0.05, CV=Coefficient of variation in percent,. *=significance level.

Table 2: Effects of inter-row spacing on yield and yield attributes of carrot for seed production at Kulumsa, during 2018 to 2019 at irrigation condition

Treatment/ (Inter-row Spacing)	Number of seed per primary branch	Seed yield per primary Umbel (g)	Seed yield per plant(g)	Seed yield kg/ha	1000 seed weight (g)
Inter-row Spacing					
50 cm × 50 cm	2571.6a	4.7075	82.3	1511.2a	1.736
75cm × 50cm	2612.4a	5.45	94.21	1574.1a	1.83
100cm× 50 cm	2133.3b	4.9238	80.94	1082.8b	1.745
Mean	2439.1	5.0271	85.81667	1389.367	1.7703
LSD	390.14	1.335	24.06	491.3	0.1988
CV (%)	15.16	25.17	26.57	29.44	10.67
Significance	*	Ns	ns	*	ns
Year					
2018	2437.3	5.7528a	79.565	1653.3a	1.8
2019	2440.8	4.3013a	92.071	1081.5b	1.73333
Mean	2439.05	5.02705	85.818	1387.4	1.766665
LSD	318.55	1.09	19.645	339.97	0.1623
CV (%)	15.1629	25.1734	26.577	29.355	10.6685
Significance	Ns	*	ns	*	ns

Means in the same column followed by the same letters are not significantly different at 5% level of significance according to Duncan's Multiple Range Test. ns=non-significant, LSD (5%)=Least significant difference at P=0.05, CV=Coefficient of variation in percent,. *=significance level.

Table 3: Simple correlation coefficients among different parameters of carrot seed production.

Pearson Correlation Coefficients, N = 12 Prob > |r| under H0: Rho=0											
	DF	DFS	SYPU	SYP	SYha	TSWt	PH	NPUP	NPBP	UDP	NSP
DF	1	0.37852*	0.15845	-0.16673	-0.48840*	0.17774	-0.47740*	0.29428*	-0.10405	0.24039*	-0.23832*
DFS		1	-0.01093	-0.09519	0.06598	0.12829	-0.61527**	0.29782*	0.01267	0.03225	-0.00169
SYPU			1	0.18377	-0.00927	0.16740	-0.09761	-0.36572*	0.00564	0.31876*	0.22636*
SYP				1	0.16049	-0.23415*	0.26232*	0.18885	0.43715**	0.59268**	0.32789*
SYha					1	0.64544**	0.10040	-0.41083*	0.52065**	-0.14420	-0.01211
TSWt						1	-0.28982	0.02728	-0.44880	0.32525*	0.01889
PH							1	0.12634*	0.21104*	0.01851	0.23670*
NPUP								1	0.17548	0.16942*	0.16788*
NPBP									1	0.35500*	0.52036**
UDP										1	0.40640*
NSP											1

DF=Days to 50% flowering, DFS= Days to fruit set, SYPU= seed yield per primary umbel, SWP= seed yield per plant, SYha= seed yield per hectare, TSWt =Thousand seed weight, PH= plant height, NPUP= Number of Primary Umbel per plant, NPBP= Number of primary branch per plant, UDP= Umbel diameter (on primary branch), NSP= Number of seed per primary branch: * = Correlation is significant at the 0.05 level: ** = Correlation is significant at the 0.05 level.

Seed yield per hectare (kg/ha)

Inter- row spacing significantly affected the seed yield per hectare ($p<0.05$). The maximum mean seed yield per hectare (1574.1kg) was recorded at row spacing of 75cmx50cm followed by 1511.2kg (50cmx50cm) and 1082.8kg (100cmx50cm) with overall mean seed yield of 1389.36kgha^{-1}. The seed yield obtained from the current study is much higher than what was stated by George (2009). According to George (2009), seed yield of open-pollinated cvs is about 600kg ha^{-1} in temperate zone. However, in tropical regions, the European cultivars yield about 300kg ha^{-1} whereas Asian cultivars produce only about 250 kg ha^{-1}. Greater the plant density, greater will be the carrot seed yield but seed quality will be poor (Noland *et al*., 1988). Mazumder *et al.* (2007) stated that plants grown under optimum population density per unit area provides optimum conditions for luxuriant crop growth and better plant canopy area due to maximum light interception, photosynthetic activity, assimilation and accumulation of more photosynthates into plant system and hence they produce more seed yield.

Thousands seed weight (g)

Thousand seed weight (TSW) was not affected by inter-row spacing ($p>0.05$). However, the maximum TSW (1.83g) was recorded from 75cmx50cm spacing while the minimum (1.736g) was from 50cmx50cm with mean value of 1.7703g. A research conducted in the past using the same variety (AUA-108) at Debrezeit Agricultural Research Center (DzARC), Ethiopia had about 1.66g TSW, which is relatively low as compared to the result of the present study. The differences could be due to differences in agro-ecologies between the two sites. The higher elevation (2200 m.a.s.l) and colder temperature of the study area favored the carrot plants to develop plump and heavy seeds compared to the low elevated (1900m.a.s.l) and hotter climate of DzARC.

Correlation analysis

Correlation coefficient (*r*) values computed to determine the relationships between and within the planting space and parameter are depicted in Table 3. The correlation analysis showed that seed yield per hectare was positively associated with most of the plant characters. For instance, Positive and statistically highly significant correlation were noted with number of primary branch per plant (r = 0.5206**), thousand seed weight (r = 0.64544**) and positively significant correlated with seed yield per plant (r = 0.1609*), plant height (r = 0.1004*) and umbel diameter (r = -0.14420), number of umbels per primary branch (r= -0.4108) and number of seed per umbel (r = -0.0121). Seed yield per plant was positively and statistically significant correlation with number of primary branch per plant (r = 0.43715*), umbel diameter on primary per plant (r = 0.59268**) and number of seed per plant (r = 0.32789*). This result also familiar with El-Adgham *et al*. (1995) reported the significant correlation of seed yield/plant with the number of second order umbels and also with the total number of umbels/plant. On the other hand, seed yield per hectare was negatively associated with days to 50% flowering (r = -0.48840*), these result could suggest that delaying planting of carrot negatively affect the flowering characters and ultimately resulted in reduced seeding potential of umbels (Table 3).

Conclusions

The current study was undertaken to investigate the influence of inter-row spacing on seed yield and quality of carrot seed. The difference in inter-row spacing brought significant variation on seed yield components of carrot. Number of harvested umbels per plant was higher in wider spacing than the closer spacing, which seems to be mainly due to less competition for nutrition and light. This less competition might have augmented more branching, ultimately producing more umbels per plant. Wider spacing (75cm x 50 cm) resulted in higher umbels per plant, greater mass and size of umbel in carrot crop. This increased production of seed per plant may be owing to well establishment of the plant which in turn resulted in production of maximum umbels per plant. As spacing increased the number of umbel per plant decreased and resulted in yield reduction on wider spacing than narrow spacing. Nevertheless, inter-row spacing did not influence the number of primary branch per plant, seed yield per plant, seed yield per primary umbel and thousand seed weight. Generally, the results of this study depicted that higher plant density (narrow spacing) greatly affected plant growth and consequently affected final seed yield of carrot plant. As a conclusion for the study area and similar agro-ecologies in the country, for a higher yield and good quality carrot seed, planting carrot stecklings using 75cm (inter-row) by 50cm (intra-row) spacing would be optimum for Haramaya 1(AUA-108) variety if used root-to-seed method.

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REFERENCES

Abayneh E, Demeke T, Gebeyehu B, Kebede A (2003). Soil of Kulumsa Agricultural Research Center. National Soil Research Center (NSRC), Soil survey and land evaluation, Technical Paper No.76.

Ahmad N, Tanki MI. (1997). Effect of planting date, spacing and stekling size on growth and seed yield of carrot. Haryana Journal of Horticulture Science.; 26:274-276.

Anam Noor, Khurram Ziaf, Muhammad Awais Ghani, Chaudhary Muhammad Ayub, Iftikhar Ahmad and Muhammad Amjad. (2020). Plant spacing effects on seed yield and quality of carrot cultivar T-29. Pure and Applied Biology (PAB). Vol. 9, Issue 4, pp2563-2570

Chhetri RK, Panta R & Shrestha RK (2019). Effect of spacing and potassium application on growth and yield of radish Raphanus Sativus cv. Mino Early. Int J Biol Res 2(1): 176- 180.

Dawit A, Abera D, Lemma D, Chimdo A (2004). Domestic vegetable seed production and marketing. Research report No 57, EARO. Addis Ababa.

El-Adgham FI, El-Shal MA, Feleafel MN (1995). A note on correlation studies in seed production of carrot var. Chantenary Red Cord. Alexandria J. Agric. Res., 40: 399-408.

George ATR (2009). Vegetable Seed Production. 3rd ed. Cambridge University Press, UK. p. 328.P226- 237.

George RAT (1999). Vegetable seed Production. 2nd ed. Cambridge University Press, UK. p. 328.

Horbe TA, Amado TJ, Reimche GB, Schwalbert RA, Santi AL & Nienow C (2016). Optimization of within-row plant spacing increases nutritional status and corn yield: A comparative study. Agron J 108: 1962-1971.

Kang ES, Ha SM, Cheong SR, Seo MW, Kwack YB, Choi KJ & Chae WB (2015). Optimum double-row spacing in the autumn cultivation of radish (Raphanus sativus L.). Korean Journal of Environ Agric 34: 204-209.

Kumar A, Afroza B, Jabeen N & Mushtaq N (2017). Manipulation of plant spacing and steckling size to increase growth and seed yield in carrot (Daucus carota L.) under temperate conditions of Kashmir. Vegetos 30(4): 1-2.

Lemma D (1998). Seed production guideline for tomatoes, onion, and hot pepper. Institute of Agricultural Research, Addis Ababa. p 22.

Mazumder, S. N., M. Moninuzzaman, S. M. M. Rahman, and N Basak. C.2007. Influence of support systems and spacing on hyacinth bean production in the eastern hilly area of Bangladesh. Leg. Res., 30(1): 1-9.

McDonald MB, Copeland LO (1998). Seed production and principles and practices CBS publishers &distributers 11, Darya Ganj, New Delhi. P 749.

Mengistu T, Yamoah C. (2010). Effect of sowing date and planting density on seed production of carrot (Daucus carota var. sativa) in Ethiopia. African Journal of Plant Science.; 4(8):270-279.

Muhammad AA, Muhammad A (2002). Influence of mother root size and plant spacing on carrot seed production. Bahauddin Zakariya University, Multan, Pakistan. Journal of Resource Science, 13(2): 105-112.

Norman, J.C. 1992. Tropical vegetable crops. Arthur H Stock well Limited, London, p.110-252.

Noland, T.L., Maguire, J.D., Oliva, R.N., Bradford, K.J., Nelson, J.L., Grabe, D. and Currans, S. (1988) "Effect of plant density on carrot seed yield and quality under seed to seed production systems in California, Oregon, and Washington", Journal. Appl. Seed Prod., 6, 36-43.

Organic Seed Alliance (2018). Carrot Seed Production-Quick Reference. Port Townsend, USA.

SAS Institute Inc. Cray. 2009. Users Guide. Version 9.2. NC.USA.

Ziaf K, Mahmood-ur-Rehman M, Amjad M, Ahmad R, Batool A, Muhammad A, Latif J & Zaman QU. (2017). Influence of hydro-and halo-priming on germination and seedling growth of cabbage under saline conditions. Pure Appl Biol 6(1): 97- 107.