African Journal of Plant Science Vol. 4(8), pp. 270-279, August 2010
Available online at http://www.academicjournals.org/AJPS
ISSN 1996-0824 ©2010 Academic Journals

Full Length Research Paper

Effect of sowing date and planting density on seed production of carrot (*Daucus carota* var. *sativa*) in Ethiopia

Tesfu Mengistu[1] and Charles Yamoah[2]*

[1]Department of Dryland Crop Sciences, Faculty of Dryland Agriculture, P. O. Box 1020, Jigjiga University, Jigjiga, Ethiopia.

[2]Department of Land Resource Management and Environmental Protection, Faculty of Dryland Agriculture, P. O. Box 231, Makelle University, Mekelle, Ethiopia.

Accepted 26 May, 2010

An experiment was conducted in 2006 and 2007 cropping seasons to investigate the effect of sowing date and planting density on yield and quality of carrot seed. The crop was grown in factorial combination of four sowing dates (mid November, December, January and February) and four different planting densities (133 333, 200 000, 266 666, and 400 000 plants/ha) in randomized block design with three replications. The plant spacing corresponding to the aforementioned densities were 50 cm × 5 cm; 50 cm × 10 cm; 75 cm × 5 cm and 75 cm × 10 cm, respectively. Both yield and seed quality declined progressively as sowing was delayed from November to February. Increasing the planting density from 133 333 plants/ha to 400 000 plants/ha increased the overall seed yield of November and December plants. However, for January and February, seed yield was observed to decline with increased planting density, because of heavy rainfall and infestation of *Alternaria* leaf blight at flowering stage. Planting density had no significant effect on seed quality ($p \leq 0.05$). Seed yield per plant significantly ($r = 0.55^*$) correlated with number of branches per plant, plant height ($r = 0.73^{**}$), umbel diameter($r = 0.780^{**}$), number of umbels per plant ($r = 0.576^{**}$), number of umbellets per umbel ($r = 0.783^{**}$) and with seed weight per umbel ($r = 0.894^{**}$).

Key words: Carrot, seed production, planting density, sowing date.

INTRODUCTION

Carrot 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). However, the seed supply from the domestic production is not adequate and growers depend mainly on imported seeds that demand foreign currency and are of questionable sources with respect to germination and susceptibility to diseases (Lemma, 1998). Thus, to improve the production and productivity of carrot domestically, the availability of quality seed is crucial (Dawit et al., 2004).

Tindall (1993) reported that carrot seeds are rarely produced in tropical conditions since mean day temperatures are less than 20°C. Experiences in Ethiopia have indicated that there are places in the country with optimum temperatures for seed production of carrot (Dawit et al., 2004). Lemma (1998) reported that in the highlands of Ethiopia with elevation above 2000 m, day and night temperatures of 15 - 25°C and 5 - 10°C, offer favorable conditions for vegetable cultivation.

Farmers in and around Kombolcha in Ethiopia are mainly engaged in vegetable crops production as a major source of income, primarily, because of its proximity to Djibouti and Somalia markets. For most of the vegetable crops, particularly the cool season ones, the growers depend exclusively on imported seeds, the high cost of which have become the major production problem. Few farmers of the area have become successful in producing their own carrot seeds despite insufficient quantities. To encourage farmers to produce adequate and quality

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

Table 1. Monthly average weather data of the study area for the year 2006/2007.

Month/year	T_{max}. (°C)	T_{min}.. (°C)	RF (mm)	RH (%)
November/2006	23.22	4.53	43.0	39.10
December/2006	21.46	7.32	87.9	52.87
January/2007	22.18	6.27	0.9	52.97
February/2007	25.62	7.62	4.8	37.82
March/2007	26.75	9.21	36.0	40.97
April/2007	25.11	13.53	133.9	53.2
May/2007	25.71	13.75	172.4	55.29
June/2007	24.96	13.81	141.8	62.47
July/2007	23.95	14.03	247.6	64.90
August/2007	23.64	14.03	207.3	71.32
September/2007	23.69	12.95	290.4	62.9
October/2007	24.48	6.03	0.0	33.87

T_{max} = average maximum temperature, T_{min}=average minimum temperature, RF= average rainfall, RH = average relative humidity.

seeds, the government should empower researchers and extension personnel to develop and extend appropriate techniques to the traditional vegetable growers.

For instance, information on sowing dates and seeding rates of carrot seed are important to the production of quality seeds but are limited or at times unavailable. Therefore, the objectives of this study are to find out the effect of sowing dates and the optimum planting density on quality seed production of carrot in the Ethiopian highlands.

MATERIALS AND METHODS

This experiment was conducted at East Hararghe (9°26" 45' N and 42° 07"07' E), Oromia region of Ethiopia. The altitude is 2115 m above sea level. It has a bimodal rainfall distribution in a semi arid agro climatic zone. The short and long rainy season extends from March to April and June to October, respectively. The total annual average rainfall is 1364 mm and the mean annual temperature ranges from 16 - 26°C (Eyasu, 2007). The type of soil is an alluvial sandy clay loam.

A factorial experiment consisting of four sowing dates (mid November, December, January and February) and four planting densities (400 000, 200 000, 266 666 and 133 333 plants per hectare) was laid out in a randomized complete block design with three replications. The plant spacing that corresponded the above densities was 50 cm× 5 cm; 50 cm × 10 cm; 75 cm × 5 cm; and 75 cm × 10 cm, respectively.

Gross and net plot sizes were 9 m^2 (3 m × 3 m) and 2.25 m^2 (1.5 m × 1.5 m), respectively. The spacing between each plots and the distance between blocks were 0.9 and 1.2 m, respectively.

Carrot seeds of local variety were sown at monthly intervals starting from mid November 2006 to February 2007. The seeds were obtained from local farmers. Apparently, farmers prefer more to use local variety than imported seeds. This is because the local varieties are found to resist breakage in the course of transportation to distant markets in neighboring countries like Djibouti and Hargessa in Northern Somalia. The rest of the produce is immediately distributed to the farmers in the farm. Fertilizer rates were 30 kg P/ha applied at planting and 30 kg N/ha applied in equal split, at planting and 6 weeks later. The source of fertilizer was di-ammonium phosphate (Rubatzky et al., 1999).

Watering and other required cultural practices were treated equally for all plots.

Data collected were percent germination after 2 weeks, days to 50% emergence, days to 50% flowering, days to maturity, plant height, number of primary and secondary branches, number of umbels(primary, secondary and tertiary) per plant, number of umbellets per umbel, umbel diameter , seed weight per umbel and per plant, disease (*Alternaria* leaf blight) incidence and severity. The statistical software for data analysis was SPSS (Statistical Package for Social Sciences).

RESULTS AND DISCUSSION

Phenology parameters

The phenology parameters showed that neither sowing date nor planting density was significant in affecting the number of days to 50% crop emergence. In all the treatments, over 50% of the seedlings emerged after 12 days of sowing (Table 1). This is the normal emergence time (10 - 15 days) of most carrot varieties (Kotecha et al., 1995).

Significance differences ($p \leq 0.05$) were recorded for days to 50% flowering and days to maturity among the planting dates and planting densities. Early flowering was observed for November plants in 153 days after sowing, that is, 14 days earlier than February plants that flowered 167 days after sowing (Table 1). The variation in days to flowering among the treatments might be due to the relative low temperature observed in the early growth stages (Table 1). Thus, the duration the plants exposed to the low temperature decreased progressively as planting was delayed from November through February.

This finding agrees with the reports of Roberts et al. (1997) who stated that if cold temperatures are experienced early in growth stages, flowering of most biennial vegetable species is increased. Lengthening the exposure of carrot to low temperatures increases

Table 2. Effects of sowing date and planting density on number of days to 50% emergence, 50% flowering and seed maturity of carrot.

Treatment	Days to 50% emergence	Days to 50% flowering	Days to maturity
Sowing date			
Mid-November	12a	153.417d	244.333d
Mid-December	12a	155.500c	253.083c
Mid-January	12a	160.833b	260.917b
Mid-February	12a	167.083a	266.667a
$LSD_{0.05}$	NS	0.552	0.798
Planting density			
400 000[1]	12a	160.083a	255.083b
200 000[2]	12a	159.250ab	256.167ab
266 666[3]	12a	159.167ab	256.167ab
133 333[4]	12a	158.338b	257.583a
CV(%)	0.00	0.849	0.763

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, CV = Coefficient of variation[1] 50 cm × 5 cm, [2] 50 cm × 5 cm , [3] 75 cm × 5 cm, [4] 75 cm × 10 cm.

vernalisation response (Sakr and Thompson, 1942; Dickson and Peterson, 1958; Hiller and Kelly, 1979).

Days to maturity was also significantly ($p \leq 0.05$) different among the treatments. November plants were the earliest to mature (244 days after planting) followed by December plants and February plants were the last to mature (267 days after planting). Heavy rainfall during flowering and maturity of the seeds could possibly be the reason for the delay in maturity of the later crops. Lemma (1998) reported that excess rainfall delays seed maturity and leads to disease pressure and flower abortion of vegetable crops.

The effect of planting density on days to 50% flowering and days to maturity was significant ($p \leq 0.05$). There was an increasing trend in days to 50% flowering with increased planting density. It ranged from 158 days for plants at low planting density (133, 333 plants /ha) to 160 days for those at high density (400,000 plants/ha) and the difference in days (that is, 158 vs. 160) was not significant (Table 2). These results were in line with the findings of Gray et al. (1983), who revealed that flowering was few days later as planting density increased from 10 - 80 plants/m^2. This could be due to the effect of competition among plants for some growth resources, such as nutrients, moisture, light etc. On the contrary increasing planting density appeared to shortened days to maturity. Accordingly, plants at high density (400 000 plants/ha) were observed to mature few days earlier than plants at low planting density (133 333 plants/ha). This 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. Gray (1981) in this study found that at the highest densities, the umbels matured more or less simultaneously, but at the lowest densities, the seeds in the primary umbel started to ripe approximately two weeks before seeds in the secondary umbel. The interaction effect of sowing date and planting density was not significant ($p \geq 0.05$) in affecting days to flowering and maturity.

Growth parameters

Significance differences were found in planting densities with regard to number of primary and secondary branches per plant (Table 3). Increasing planting density resulted in a decreased number of branches. Plants spaced 75 cm × 10 cm (133 333 plants/ha) gave the highest number of both primary and secondary branches followed by plants spaced 50 cm × 10 cm (200 000 plants/ha). The least number of branches were recorded for plants spaced 50 cm × 5 cm (400 000 plants/ha). Earlier reports by Gray and Steckel (1983) showed similar results, where growing carrot seed crops at high density reduced the number of lateral branches. Muhammad and Muhammad (2002) demonstrated increased number of branches per plant in widely spaced plants than in closely spaced ones. This may be due to competition for space, nutrients, light and air between the plants (Muhammad and Muhammad, 2002). The effect of sowing date and its interaction with planting density was found to be non-significance ($p \geq 0.05$) in affecting the number of branches per plant.

Table 3. Growth parameters of carrot as affected by sowing dates and planting density.

Treatment	No. of primary branches	No. of secondary branches	Plant height (cm)
Sowing date			
Mid-November	7.17a	13.07a	167.22a
Mid-December	6.92a	12.75a	166.03a
Mid-January	6.88a	12.42a	141.14b
Mid-February	6.85a	12.73a	140.24b
Planting density (plants/ha)			
400 000[1]	5.85d	10.05c	153.72a
200 000[2]	7.47b	12.63b	152.77a
266 666[3]	6.28c	13.07b	154.82a
133 333[4]	8.22a	15.22a	153.32a
CV (%)	5.34	6.81	3.07

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, CV=Coefficient of variation [1] 50 cm × 5 cm, [2] 50 cm × 5 cm, [3] 75 cm × 5 cm, [4] 75 cm × 10 cm.

There was significance difference ($p \leq 0.01$) in plant height among the sowing dates. November and December plants were significantly taller than January and February plants (Table 3). The variation in plant height of the respective planting dates might be due to the effect of temperature on the level and activity of gibberellins, substances responsible for elongation of flower stalk. Earlier reports indicated that low temperature treatments resulted in both quantitative increase and qualitative changes in gibberellic acid (GA) levels (Kruzhilin and Shvedsksya 1960; Thomas et al., 1972; Jones, 1973). As discussed earlier, November and December plants' long exposure to low temperature during vernalization might have promoted the level and activity of GA more than that of January and February plants. Hiller et al. (1979) noted a decreased carrot seed stalk elongation and endogenous GA-like activity with high temperatures following vernalization. Plant density and its interaction with sowing date had no significance ($p \geq 0.05$) effect on plant height. Gray (1981) reported a non-significant effects of plant density of 110 000 - 2 560 000 plants/ha.

Flowering characters

Data on number of secondary and tertiary umbels per plant showed significant differences ($p \leq 0.01$) among planting densities. 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 (Table 4). 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. George (1999) indicated the decreased number of umbels per plant with increasing plant density, supporting the findings of this study. However, the effect of planting date and its interaction with planting density was not significant ($p \geq 0.05$) in affecting the number of umbels per plant.

The size of umbels and the number of umbellets per umbel of each order (primary, secondary and tertiary) were significantly different ($p \leq 0.01$) among planting dates (Table 4). November and December plants gave larger umbel size and greater number of umbellets per umbel of each order than January and February plants. The variation in flowering characters among the sowing dates could probably be related to the level and activity of endogenous gibberellins, substances known to enhance flowering characters in low temperatures (Rubatzky et al., 1999). November and December plants' long exposure to low temperature might have led to better flowering characters, as exhibited in umbel size (diameter) and number of umbellets per umbel than January and February plants. Quagliotti (1967) noticed increased number of umbellets per umbel and number of flowers per umbellet, at lower temperatures. Ghoname et al. (2004) found that carrot seed treated with GA gave the best results with respect to number of days for flowering, seed stalk height, umbel diameter and weight and number of umbels per plant. Therefore, this substantiates the role of gibberellins in enhancing flowering of carrot, which is often triggered by low temperatures.

The interaction of planting density with sowing date was not significant ($p \geq 0.05$) in influencing the size of umbel and number of umbellet per umbel of each order.

Seed yield and yield components

Average seed weight per a primary, secondary and tertiary umbel of a carrot plant showed significant ($p \leq 0.05$) differences for the different planting dates and

Table 4. Effects of sowing date and planting density on number of umbels per plant, number of umbellets per umbel and umbel size (diameter).

.	Number of umbels per plant		Number of umbellets per umbel			Umbel size(diameter)(cm)		
	Secondary	Tertiary	Primary	Secondary	Tertiary	Primary	Secondary	Tertiary
Sowing date								
Mid-Nov.	5.733a	8.363a	117.883a	95.515a	76.533a	15.442a	10.583a	5.750a
Mid-Dec.	5.533a	8.160a	117.208a	95.133ab	76.300a	15.317a	10.533a	5.700a
Mid-Jan.	5.507a	7.947a	108.067b	91.950ab	71.150b	13.725b	9.625b	5.275b
Mid-Feb.	5.480a	8.149a	107.867b	91.083b	70.800b	12.725c	8.658c	5.217b
$LSD_{0.05}$	NS	NS	2.603	0.441	0.368	0.137	0.048	0.052
Planting density (plants/ha)								
400 000[1]	4.680d	6.432c	110.721a	92.890a	73.217b	14.142b	9.792b	5.425b
200 000[2]	5.973b	8.085b	111.338a	93.165a	73.567ab	14.300ab	9.842ab	5.475ab
266 666[3]	5.027c	8.363b	114.052a	93.592a	73.767ab	14.292ab	9.842ab	5.475ab
133 333[4]	6.573a	9.739a	114.915a	94.035a	74.233a	14.475a	9.925a	5.567a
$LSD_{0.05}$	0.121	0.227	NS	NS	NS	NS	NS	NS
CV (%)	5.33	6.82	5.65	1.15	1.22	2.34	1.2	2.31

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, CV=Coefficient of variation. [1] 50 cm × 5cm, [2] 50 cm × 5 cm, [3] 75 cm × 5 cm, [4] 75 cm × 10 cm.

densities (Table 5). The results indicated that seed weight per umbel tended to decline progressively from November to February planting dates. Thus, the highest seed weight per umbel of each order was recorded for November plants (2.00, 1.07 and 0.11 g) whereas, the least was for February plants (0.60, 0.34 and 0.03 g), for the respective primary, secondary and tertiary umbels (Table 5). High rainfall might have resulted in flower abortion and the occurrence of diseases during flowering of the later plantings. Ogawa (1961) noticed that under continuous rainfall, flowering and seed set of onion were significantly reduced. Flowering characteristics expressed as umbel size and number of umbellets, were observed to decline progressively along with the respective planting dates. Besides, the population and effectiveness of pollinating insects might have an impact on seed yield of carrot. Visual observation indicated that the population and activity of pollinating insects were enormous during the flowering periods of November and December. However, for January and February plants, whose flowering coincided with the rainfall period, the population as well as activities of the pollinating insects was remarkably reduced. Bees and flies were the dominant insect species observed visiting carrot flowers at that time.

Similarly, increasing planting density considerably reduced the mean seed weight per umbel of each order. Accordingly, plants at low planting density (133333 plants/ha) gave the highest mean seed weight (1.27, 0.69 and 0.08 g) for primary, secondary and tertiary umbels, respectively.

The lowest seed weights (1.08, 0.60 and 0.05 g) were observed at high planting density of 400 000 plants/ha for primary, secondary and tertiary umbels, respectively (Table 5). The finding of this study is in conformity with those of Muhammad and Muhammad (2002) who reported increased seed weight per umbel with increased plant spacing. This could be due to less effect of competition among plants for growth resources such as water, nutrient, light, oxygen and carbon dioxide and in pollinating agents (Norman, 1963). The results indicated that, the maximum seed weight per umbel was obtained in the primary umbels, which significantly differed from secondary and tertiary umbels. The tertiary umbels resulted in minimum seed weight, which may be due to their smaller size and less time available to develop (Muhammad and Muhammad, 2002).

The main effects of sowing dates and planting

Table 5. The interaction effect of sowing date and planting density on seed weight per umbel order of carrot (g/ umbel).

Planting density	Primary umbel					Secondary umbel					Tertiary umbel				
SD / PD	Nov	Dec.	Jan.	Feb	Mean	Nov	Dec	Jan	Feb	Mean	Nov	Dec	Jan	Feb	Mean
400 000[1]	1.845	1.389	0.604	0.470	1.08d	1.023	0.760	0.330	0.281	0.60c	0.094	0.055	0.018	0.013	0.05c
200 000[2]	2.046	1.444	0.614	0.600	1.18c	1.072	0.829	0.436	0.320	0.66b	0.106	0.072	0.034	0.030	0.06b
266 666[3]	2.005	1.456	0.814	0.625	1.23b	1.066	0.806	0.381	0.365	0.65b	0.110	0.079	0.050	0.034	0.07ab
133 333[4]	2.091	1.488	0.828	0.680	1.27a	1.119	0.867	0.544	0.401	0.69a	0.113	0.082	0.059	0.045	0.08a
Mean	2.00a	1.44b	0.72c	0.59d		1.07a	0.82b	0.42c	0.34d		0.11a	0.07b	0.04c	0.03d	
LSD$_{(0.05)}$															
SD	0.021					0.013					0.005				
PD	0.021					0.013					0.005				
SD*PD	0.030					0.019					NS				
CV (%)	4.61					4.77					0.00				

Means in the same column or row followed by the same letters are not significantly different at 5% level of significance according to Duncan's multiple range test. SD = sowing date, PD =Planting density, NS = non significant, CV=Coefficient of variation[1] 50 cm × 5cm, [2] 50 cm × 5 cm, [3] 75 cm × 5 cm, [4] 75 cm × 10 cm.

densities as well as their interaction significantly affected seed yield (p ≤ 0.01), the seed yield per plant and per hectare decreased significantly with a delay in planting (Table 6).

It ranged from 5.37 g/plant and 1007 kg/ha for November to 1.43 g/plant and 243.22 kg/ha for February plants. In delayed planting umbel diameter, number of umbellets per umbel and seed weight per umbel were significantly less which might have inevitably reduced the seed yield. Thus, increasing the plant density from 133 333 - 400 000 plants/ha reduced the mean seed weight per plant from 4.57 - 2.10 g (Table 6). This is because of the less number of productive umbels obtained per plant at higher plant density (Gray and Steckel, 1983).

Muhammad and Muhammad (2002) explained the increased seed yield per plant with increasing plant-to-plant distance. Gray et al. (1983) also reported that, as planting density increased, there is a reduction in the number of high order secondary umbels and number of seeds on each umbel order. However, the reverse holds true when yield was expressed on per hectare basis, because fewer seed from more plants might have resulted in higher total yield (Rubtazky et al., 1999). Several authors reported that carrot seed yield (kg/ha) generally increase with plant population (Jacobsohn and Globerson, 1980; Gray, 1981; George 1999; Muhammad and Muhammad, 2002).This study showed that raising the planting density to 400, 000 plants/ha brought a seed yield advantage (8.41%) as compared to the planting density of 133 333 plants/ha. Nevertheless, the yield advantage gained over the planting densities varied significantly among the different planting dates. As illustrated in Table 6, increasing planting density from 133 333 - 400 000 plants/ha resulted in a yield advantage of 19.59 and 8.62% for November and December, respectively. On the contrary, in January and February, increasing planting density appeared to reduce yield by 13.78 and 7.96%, respectively. The decline in yield of the later plants could be due to the incidence of *Alternaria* leaf blight which was observed to occur late after the on set of the rain and whose severity was much more pronounced in narrowly spaced row plants. The

Table 6. The interaction effect of sowing date and planting density on seed yield of carrot expressed as gram per plant and kg per hectare basis.

PD \ SD	Seed yield per plant (g)				Mean	Seed yield per hectare (kg)				Mean
	Nov	Dec.	Jan.	Feb		Nov	Dec	Jan	Feb	
400 000[1]	3.906	2.574	1.041	0.886	2.10d	1116.815	711.585	286.163	229.345	585.98b
200 000[2]	5.201	3.911	1.722	1.370	3.05b	970.756	688.948	283.407	235.319	544.61b
266 666[3]	4.655	3.298	1.685	1.242	2.72c	1006.563	694.830	348.385	260.607	577.60ab
133 333[4]	7.711	5.332	3.040	2.200	4.57a	933.867	655.111	325.585	247.600	540.54a
Mean	5.37a	3.78b	1.87c	1.43d		1007.00a	687.62b	310.89c	243.22d	
$LSD_{(0.05)}$										
SD		0.137					18.843			
PD		0.137					18.843			
SD*PD		0.194					26.648			
CV (%)		10.81					8.21			

Means in the same column or row followed by the same letters are not significantly different at 5% level of significance according to Duncan's Multiple Range ..Test. SD=Sowing date, PD=Planting density, CV=Coefficient of variation, NS = non significant[1] 50 cm × 5cm, [2]50 cm × 5 cm, [3]75 cm × 5 cm, [4]75 cm × 10 cm.

disease is reported to cause a significant yield loss in carrots (McDonald and Copeland, 1998).

Seed quality parameters

The term seed quality encompasses several attributes of seeds among which thousand seed weight (TSW), germination percentage and germination rate were used in this study.

Thousand seed weight, germination percentage and germination rate were significantly ($p \leq 0.01$) different among the planting dates. November plants were of slightly higher TSW (0.84 g). However, crops planted from December onwards did not show any significance difference in TSW. Similarly, germination percentage and rate were significantly ($p \leq 0.01$) higher and faster for November plants (80.8% and 6.8 days, respectively) (Table 7) than the other planting dates. The incidence of heavy rain and *Alternaria* leaf blight during maturity might have deteriorated the quality of seeds contributing to the poor germination rate. The results signify the association between germination percentage and mean germination rate, where seeds with high germination percentage had short mean germination time. This agrees with the finding of Gray (1984). Nevertheless, in the range of planting densities used in the study, these quality parameters did not show any significant ($p \geq 0.05$) difference, implying that sowing dates are more important in affecting seed quality than planting density. Studies reported by Kong et al. (2004) showed that high density increased the seed yield per unit area without significant effects on seed quality.

Disease incidence and severity

The severity of *Alternaria* leaf blight was significantly ($p \leq 0.01$) different among the different planting dates and planting densities (Table 8) showing that the incidence and severity of the disease increased significantly with a delay in planting. The occurrence of the disease seemed to be related with the weather pattern particularly to rainfall. Rubatzky et al. (1999) reported that rain and sprinkler irrigation favor the development of Alternaria leaf blight and its incidence further increased with high humidity and temperatures of 14 - 35°C. Therefore, as indicated in the weather data (Table 1) the weather condition, particularly the rainfall and the relative humidity during flowering and seeding late in January to February seemed to be more favorable for the disease development than plants in early November. Obviously, delayed planting exposes crops to pest and diseases infestation including *Alternaria* leaf blight.

Correlation analysis

The correlation analysis showed that seed yield per plant was positively associated with most of the plant characters. For instance, highly significant correlation ($p \leq 0.01$) were noted with seed yield per plant and number of branches per plant (r = 0.546**), plant height (r = 0.734**), umbel diameter (r = 0.780**), number of umbels per plant (r = 0.576**), number of umbellets per umbel (r = 0.783**) and with seed weight per umbel (r = 0.894**) (Table 9). These characters are the most important attributes of seed yield per plant. El-Adgham et al. (1995) reported the significant correlation of seed yield/plant

Table 7. Effects of sowing date and planting density on seed quality parameters of carrot.

Treatment	TSW	Germination percent	Germination rate
Sowing date			
Mid-November	0.840a	80.777a	6.812c
Mid-December	0.837ab	62.416b	7.981b
Mid-January	0.831b	48.611c	9.515a
Mid-February	0.831b	29.277d	9.623a
$LSD_{0.05}$	0.004	1.757	0.083
Planting density			
400 000[1]	0.838a	53.971a	8.433b
200 000[2]	0.833a	55.167a	8.480b
266 666[3]	0.836a	57.722a	8.405ab
133 333[4]	0.832a	56.611a	8.614a
CV(%)	0.00	7.79	2.42

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, CV=Coefficient of variation. [1]50 cm × 5 cm, [2] 50 cm × 5 cm, [3] 75 × 5 cm, [4] 75 cm × 10 cm.

Table 8. Effects of sowing date and planting density on incidence and severity of *Alternaria* leaf blight of carrot.

Treatment	Disease incidence	Severity index
Sowing date		
Mid-November	28.333d	20.140d
Mid-December	48.333c	32.223c
Mid-January	70.000b	40.189b
Mid-February	81.667a	46.403a
Planting density		
400 0001	70.000a	40.967a
200 0002	64.167b	38.349a
266 6663	50.833c	30.613b
133 3334	43.333d	29.028b
CV (%)	11.457	9.320

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.
CV=Coefficient of variation. [1] 50 cm × 5cm, [2] 50 cm × 5 cm, [3] 75 cm × 5 cm, [4] 75 cm × 10 cm.

with the number of second order umbels and also with the total number of umbels/plant.

On the other hand, seed yield per plant was adversely associated with days to 50% flowering (r = -0.819**), days to maturity (r = -0.758**), incidence and severity of *Alternaria* leaf blight (r = -0.895** and -0.864**, respectively) (Table 9). The results could suggest that delaying planting of carrot negatively affect the flowering characters and ultimately resulted in reduced seeding potential of umbels. The incidence and severity of *Alternaria* leaf blight was more common in plants sown late after December, whose flowering stage met with the summer heavy rain and high relative humidity (Table 1).

CONCLUSIONS AND RECOMMENDATIONS

The current study was undertaken to investigate the effects of sowing date and planting density on yield and quality of carrot seed. The results indicated that except for days to emergence, all the evaluated parameters were significantly affected either by sowing date or plant density or by both. Plant densities did not significantly affect plant height, umbel size (diameter), number of umbellets per umbel, thousand seed weight, germination percentage and rates. Similarly, sowing dates did not influence the number of primary and secondary branches per plant.

The results of this study identified the appropriate

Table 9. Simple correlation coefficients among different parameters.

Plant characters	DTF	DTM	NBP	PH	UD	NUU	NUP	SWU	TSW	DI	DS	SYP
DTF		0.903**	-0.171	-0.818**	-0.933**	-0.790**	-0.181	-0.900**	-0.357**	0.804**	0.806**	-0.819**
DTM			0.023	-0.838**	-0.869**	-0.736**	0.007	-0.937**	-0.468**	0.802**	0.803**	-0.758**
NBP				0.051	0.158	0.222	0.919**	0.226	-0.214	-0.353*	-0.321*	0.546**
PH					0.898**	0.758**	0.075	0.887**	0.416**	-0.784**	-0.728**	0.734**
UD						0.773**	0.140	0.892**	0.341*	-0.833**	0.797**	0.780**
NUU							0.275	0.819**	0.321*	-0.737**	-0.731**	0.783**
NUP								0.235	-0.218	-0.420**	-0.383**	0.576**
SWU									0.376**	-0.903**	-0.895**	0.894**
TSW										-0.286*	-0.238	0.192
DI											0.967**	-0.895**
DS												-0.864**
SYP												

DTF=Days to 50% flowering, DTM= Days to maturity, NBP= Number of branches per plant, PH= plant height, UD= Umbel diameter, NUU= Number of umbellets per umbel, NUP= Number of umbels per plant, SWU= seed weight per umbel, TSW =Thousand seed weight, DI= Disease incidence, DS =Disease severity, SYP= seed yield per plant.
* = Correlation is significant at the 0.05 level.
** = Correlation is significant at the 0.01 level.

sowing dates and planting density that would help optimize the yield and quality of carrot seed. Yield and quality of carrot seed progressively deteriorated as planting was delayed from November to February. Seed yield per plant was significantly correlated with numbers of branches per plant, plant height, umbel diameter, number of umbels per plant, number of umbellets per umbel and seed weight per umbel. Although increasing plant density has increased the overall seed yield, it was observed that carrots planted in 50 cm inter row spacing posed weeding problems. Irrigation and delayed harvesting also exacerbated the incidence and severity of *Alternaria* leaf blight, therefore inter rows spacing of 75 cm for the seed-to-seed method of carrot production is preferred to 50 cm. It is recommended that the crop's potential to flowering and quality seed production should also be investigated using root-to seed method in different sowing dates.

REFERENCES

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

Dickson MH, Peterson CE (1958). Hastening greenhouse seed production for carrot breeding. Proceedings of the American Society for Horticultural Science 71: 412-415.

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

Ghoname AA, El-Tohamy WA, Abou-Hussein SD (2004). Effect of the application method and concentrations of GA_3 on flowering, seed yield and its quality of carrot under Egyptian conditions. Ann. Agric. Sci. (Cairo) 49(1): 253-269.

Gray D (1981). Are the plant densities currently used for carrot seed production too low? Acta Hort. 111: 159-165.

Gray D (1984): The performance of carrot seeds in relation to their viability. Ann. App. Biol., 104: 559-565.

Gray D, Steckel JRA (1983). Some effects of umbel order and harvest date of carrot seed crop on seed variability and seedling performance. J. Hort. Sci., 58: 73-82.

Gray D, Steckel JRA, Ward JA (1983). Studies on carrot seed production: Effects of plant density on yield and components of yield. J. Hort. Sci., 58: 83-90.

Hiller LK, Kelly WC (1979). Effects of post-vernalization temperature on seed stalk elongation and flowering in carrots. J. Am. Soc. Hort. Soc., 104: 257-262.

Hiller LK, Kelly WC, Powell LE (1979). Temperature interactions with growth regulators and endogenous gibberellin-like activity during seed stalk elongation in carrots. American Society of Plant Physiologists. Plant Physiol., 63(6): 1055-1061.

Jacobsohn R, Globerson D (1980). *Daucus carota* (carrot) seed quality: II The importance of the primary umbel in carrot seed production. In seed production, Hebblethwaite P.D. (ed.) Butterworth, London-Boston. pp 637-646.

Jones RL (1973). Gibberellins: Their physiological role. Ann. Rev. Plant Physiol., 24: 571-598.

Kong LJ, Zhang GX, Yao DW (2004). Seed production technology of carrot in foreign countries. China Veg., 2: 54-56.

Kotecha PM, Desai BB, Madhavi DL (1995). Carrot. In: Salunkhe D.K. and Kadam S.S. (eds.) Hand book of vegetable science and thechnology, production, composition, storage and processing. Marcel Dekke . Inc. Newyork, Basel, Hongkong. pp. 119-139.

Kruzhilin AS, Shvedskaya ZM (1960). Differentiation of growing points in biennial root crops. Sov. Plant Physiol., 7: 361-365.

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

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

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

Norman AG (1963). Influence of hybrids and plant density on grain yield and stalk breakage in corn grown in 15 inch row spacing. J. Prod. Agric., 1:190-195.

Ogawa T (1961). Studies on seed production of onion. In (effects of rainfall and humidity on fruit setting). J. Japan Soc. Hort. Sci., 30: 222-32.
Quagliotti L (1967). Effects of different temperatures on stalk development, flowering habit and sex expression in the carrot *Daucus carota* L. Euphytica. 16: 83-103.
Roberts EH, Summerfield RJ, Ellis RH, Craufurd PQ, Wheeler TR (1997). The Induction of Flowering. In: Wien, H.C. ed. The Physiology of Vegetable Crops. Cambridge University press, Cambridge. p. 672.
Rubatzky VE, Quiros CF, Simon PW (1999). Carrots and related vegetable umbelliferae. CABI publishing, UK. p. 294.
Sakr S, Thompson HC (1942). Effects of temperatures and photoperiod on seedstalk development in carrot. Proceeding of the American Society for Horticultural Science 41: 343-346.
Thomas TH, Lister JN, Salter PJ (1972). Hormonal Changes in the stem apex of the cauliflower plant in relation to curd development. J. Hort. Sci., 47: 449-455.
Tindall HD (1993). Vegetables in the tropics The Macmillan press Ltd. Hound mills, Basingstoke, Hampshire. p. 553.