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The Efficacy of Sowing Date and Planting Density on Yield and Quality Seed Production of Carrot (*Duacus Carota* l.) In Highlands of Ethiopia: A Review

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Abstract

Carrot (*Daucus carota L.*) is one of the most popular and ancient vegetable crops grown throughout the world. However, in Ethiopia and other tropical countries, its production is limited by many constraints of which unavailability of seed is the most important. Therefore, this paper is undertaken to review the efficacy of sowing date and planting density on yield and quality of carrot seed production. To optimize the yield and quality of carrot seed identifying the appropriate sowing dates and planting density would help. Seed yield per plant was significantly correlated with numbers of branches per plant, plant height, umbel diameter, and number of umbels per plant, number of umbellets per umbel and seed weight per umbel. The seed yield per plant and per hectare decreased significantly with a delay in planting from November to January. Irrigation and delayed harvesting also exacerbated the incidence and severity of Alternaria leaf blight; therefore, it should be using the recommend inter rows spacing for both seed-to-seed and root-to-seed carrot production methods. Generally, it realized from this review sowing date and planting density affect carrot seed quality and yield. However, there were a possible way to alleviate the problem by selected a local improved variety (Harmaya I) and sowing this variety at a right time with optimum plant density. The recommend inter rows spacing for both seed-to-seed and root-to-seed carrot

production methods 20 m-30 cm and 50 cm-75 cm respectively for good quality and high yield of carrot seed production.

Keywords: Carrot; Seed production; Planting density; Sowing day

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Introduction

Carrot (*Daucus carota* L.) is a widely grown root vegetable of the *Apiaceae* family. The first certain recorded use of carrot roots as a vegetable was in the 10th century in what is today known as Afghanistan. Orange carrots first appeared as a genetic variant in Europe in the 16th century and these more refined orange carrots quickly spread around the world, and by the early 20th century they became the predominate carrots in most growing regions of the world. Carrot is grown from true seeds and its successful production is dependent upon a sustainable and satisfactory supply of good quality seed [1,2]. Although the exact time of introduction of carrots to Ethiopia is not known, the crop has been known since the early 1960s in the research system. In Ethiopia research on carrots was began at Alemaya College of Agriculture (now Haramaya University) using imported seeds of eight varieties from Kenya in the early 1960s.

Among the eight varieties tested, Nantes and Chantenay were identified as high yielders. Carrot production has been expanding since then and the total production reached 12345.8 tons on 2215 hectares of land (CSA, 2010/2011). 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 [2,3]. Thus, the availability of quality seed is crucial to improve the production and productivity of carrot domestically.

Experiences in Ethiopia have showed that there are places in the country with ideal temperatures for seed production of carrot. Lemma reported that in the highlands of Ethiopia favorable conditions for vegetable cultivation with elevation above 2000 m, night and day temperatures of 5°C-10°C and 15°C-25°C respectively. In Ethiopia, farmers in and around Kombolcha are mainly engaged in vegetable crops production as a main source of income, principally, because of its nearness to Djibouti and Somalia markets [4].

The growers entirely depend on imported seeds for most of the vegetable crops particularly the cool season which are exposed to high cost i.e. the main production problem. Because of niche market in neighboring Djibouti and Somalia the Nantes carrot has become popular in Hararghe Zone of Ethiopia, and produces quality roots.

Few farmers of the area have become fruitful in making their own carrot seed contempt inadequate amounts. To encourage farmers to produce adequate and quality 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.

Objective

The objective is to review the efficacy of sowing date and the optimum planting density on yield and quality seed production of carrot in the Ethiopian highlands.

Review of Literature

Phenology parameters

Phenology is the study of the onset and duration of the different phases of a plant's development during the year. Temperature, moisture, relative humidity and day length control the timing of these phases. Temperature and moisture are especially important. The rate of chemical reactions increases with warmer temperatures, and nearly all physiological processes involved in plant growth are controlled by temperature. The opening of buds, the growth of leaves, shoots and roots, the onset of flowering, seed ripening, and seed germination are all initiated by specific temperature regimes.

As I have understood from different researchers and Experts the phenology parameter showed that both sowing and planting density was not significantly affecting the number of days to 50% crop emergence. The most of the carrot varieties normal emergence time is 10 days-15 days [5].

Among the planting dates and planting densities recorded days to 50% flowering and days to maturity showed a significance difference. Early flowering was observed for November plants in 153 days after sowing, that is, 14 days earlier than February plants those flowered 167 days after sowing [6]. The variation in days to flowering among the treatments might be due to the relative low temperature observed in the early growth stages. The duration of the plants exposed to the low temperature decreased the growth stages and flowering periods progressively. Flowering of most biennial vegetable species is increased if cold temperatures are experienced early in growth stages. Lengthening the exposure of carrot to low temperatures increases vernalisation responses [7,8]. Heavy rainfall during flowering and maturity of the seeds could possibly be the rationale for the delay in maturity of the later crops. It was reported that excess rainfall delays the seed maturity and results in disease pressure and flower abortion of vegetable crops. Flowering is few days later as planting density increases from 10 plants/m^2-80 plants/m^2. Are the plant densities currently used for carrot seed production too low? In symposium on vegetable and flower seed production. This implies that the effect of competition among plants for a few growth resources, like nutrients, moisture, light etc. On the contrary increasing planting density seemed 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), the higher plant densities could shorten the general flowering period and increased the evenness in umbel ripening [9].

This may flow from to the very fact that higher plant densities considerably reduce the event of upper order umbels, letting a degree of umbels to be produced within the upper part of individual plant stalk. In this review also found that at the very best densities, the umbels matured more or less simultaneously, but at rock bottom densities, the seeds within the primary umbel started to ripe approximately fortnight before seeds within the secondary umbel.

Agronomic practices used for seed production

The objective in growing carrots is a high yield of straight, smooth roots. The first requirement is a deep, well-drained, well-prepared soil of a loose, friable structure. Sandy loam or loam soils are most suitable, if well-fertilized and irrigated, because roots then tend to be smoother, straight and have a better appearance; roots are also easier to wash clean at harvest. Carrots grow poorly in very acid soil with a pH of 5 and lower. Soil salinity and brackish soils should be avoided because carrots are very sensitive. Heavy, stony, compacted or poorly-drained soils restrict with good root development and are less fit.

Attempts to produce carrot seeds from an adapted variety (Nantes) were started at Holeta, Bokoji, Meraro and Alemaya (IAR, 1977; IAR, 1986). A single observation trial was conducted on 36m^2 plots at Bokoji (2700 meter above sea level (m.a.s.l.)). The roots which were grown at Nazareth (1600 m.a.s.l.) were planted at Bokoji on 22 June 1978 at a spacing of 40 cm between plants and 90 cm between rows. The plants flowered on 22 November 1978 and harvesting was started on 6 February 1979 and ended on 30 May 1979. The resulting seed produced had 81% germination. The seeds produced at Bokoji were planted at Kulumsa (240 m.a.s.l.) to test if they could produce good quality edible roots and for similarity to the parent Nantes. The seeds gave roots with reasonable size, shape and taste [10].

Research results conducted in the highlands of Ethiopia indicated that good quality seed could be produced from Nantes and Chantenay varieties of carrot especially at Bokoji and Meraro (Arsi highlands), Lai Gaint (South Gonder highlands) and Ankober (North Shewa highlands, 3100 m.a.s.l.) showed that seeds could be successfully produced. Carrots gave about 1000 kg/ha, 1070 kg/ha and 586.2 kg/ha seeds at Meraro, Lai Gaint and Ankober, respectively.

Seed yield and percent germination of seeds produced from domestic seeds was slightly higher than imported seeds. Seed-root-seed method was used for seed production where roots for seed were produced in the same manner as for fresh market. The roots (stecklings) were stored until planting and planted on well drained soils to avoid the development of bacterial soft rot when there was no danger of frost. The soil was well firmed around the roots and the crown was level with the surface. The seed to seed method was not used as it required the original seed to be of very high quality since there was no possibility of selecting the stecklings.

Roots grown for seed were planted 75 cm apart. The plants were fertilized with 175 kg/ha of DAP, which was the recommended rate for root production for fresh market (ARARI, 2005). Consequently, the root-to-seed method of seed production, a two phase production method, was adopted to adapt to such incidents. The method involves production of roots in the first season, sorting for best roots and then planting the roots to produce seeds.

Nowadays Harmaya University released a new carrot variety (Haramaya 1) from the locally collected 64 genotypes through successive selections. Farmers maintained and used the genotypes for a long period through an open pollinated seed production system. The genotypes were selected for adaptation to diverse environments, root uniformity, good root texture, high yield, small core diameter and resistance to cracking. The mass selection using root-to-seed production method was wanted to improve the crop.

The released variety (Haramaya I) can be grown medium to high altitudes in eastern Ethiopia (1600 m.a.s.l.-2400 m.a.s.l.) and similar areas of the country either under rain-fed or irrigation. It has a deep orange root color. The released variety has good-looking root size and shape, long roots with small cores. The variety was released mainly for its total root yield advantage of 11.41% and 16.23% over the commercial Nantes variety and the farmers' open pollinated cultivar, respectively. It has also 5.82% and 6.48% marketable root yield advantage over the commercial Nantes variety and farmers' open pollinated cultivar, respectively [11] **(Table 1)**.

Growth parameters

As many researchers and experts written and reported that one of the major problems confronting most carrot growers is to achieve the correct plant population. Number of primary and secondary branches per plant revealed significance differences in planting densities. It showed the decreased number of branches due to increasing planting density. Earlier reports showed that growing carrot seed crops at high density reduced the number of lateral branches. It is demonstrated that decreased number of branches per plant in closely spaced plants than in widely spaced plants. This may be due to competition for space, nutrients, light and air between the plants [12,13].

Very low temperature is a common experience from October to January in the cool highland of Ethiopia. The low temperature (vernalization) stimulates flower initiation and the subsequent flowering and seed set. The warm temperature between February and mid-September favours seed stalk development and seed maturity.

Planting date studies conducted in the highlands of Ethiopia showed that carrots sown in March in Ankober (3100 m.a.s.l) and those grown in September in Lai Gaint gave the highest seed yield and good quality seeds **(Table 2)**. Eastern Ethiopia farmers in and around Kombolcha also tried and could successfully produce their own carrot seeds though in small quantities. A trial on sowing date and seeding rates of carrot for seed production was conducted in the area to assist the efforts of the farmers.

Seeds of local carrots were planted at different planting dates from mid-November to mid-February at the interval of one month. Days to 50% flowering was delayed from 153 to 167 days while dates to seed maturity delayed from 244 to 267 days as sowing was delayed from mid-November to mid-February. The number of secondary and tertiary umbels, primary, secondary and tertiary umbellets per umbel decreased in mid-January and mid-February sowings compared to those in mid-November and mid-December.

On the other hand, the number of primary and secondary branches increased from 5.9 to 8.2 and 10 to 15, respectively, as plant density decreased from 400 thousand to 133 thousand per ha. Similarly, the number of secondary and tertiary umbels per plant increased from 4.7 to 6.6 and from 6.4 to 9.7, respectively. Three to four pickings of individual branches were necessary to collect all the seeds. The branches were then put in windrows for drying and then threshed when the seed had thoroughly dried.

There was significance difference in plant height among the sowing dates. November and December plants were significantly taller than January and February plants. The variation in plant height of the respective planting dates might be due to the effect of temperature on the level and activity of gibberellin substances responsible for elongation of flower stalk. As Thomas reported that low temperature treatments caused in both quantitative increase and qualitative changes in Gibberellic Acid (GA) levels [14]. Research indicated that January and February plants long exposure to low temperature during vernalization might have promoted the level and activity of GA less than that of November and December plants. Hiller 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 effect on plant height. Gray (1981) reported a non-significant effects of plant density of 110 000 plants/ha-25 60 000 plants/ha.

Table 1: Agronomic and morphological characteristics of Haramaya I carrot variety and the commercial *Nantes* carrot variety.

Characteristics	Haramaya I (AUA-108)	Nantes
Adaptation area	Medium to high altitudes of eastern Ethiopia (1600 m.a.s.l.-2400 m.a.s.l.)(metres above sea level)	Medium to high altitudes (1600 m.a.s.l. -2400 m.a.s.l.) (metres above sea level)
Rainfall (mm)	760 mm-1010 mm	760 mm-1010 mm
Planting season	Year-round both under rain-fed and irrigated conditions	All year round both under rain-fed and irrigation
Planting date	At the start of the main rainy season (June) and at any time with irrigation considering the frost period	At the start of the main rainy season (June) and at any time with irrigation considering the frost period
Seeding rate (kg ha-1)	3.5 to 5	3.5 to 5
Row spacing (cm)	25	25
Spacing between plant (cm)	5	5
Fertilizer rate (kg ha-1)	46 kg P2O5 or100 kg DAP and 64 kg N or100 kg Urea (18% N from100 kg DAP)	46 kg P2O5 or100 kg DAP and 64 kg N or 100 kg Urea (18% N from100 kg DAP)
Fertilizer application time	All DAP at planting but half of the N at planting and the remaining half at active growth stage	All DAP at planting but half N rate at planting and half at active vegetative growth stage
Fertilizer application method	Drilling in row	Drilling in row
Leaf length (cm)	55.71	58.65
Leaf width (cm)	39.8	40.83
Root colour	Deep orange	Orange
Root core diameter (cm)	2.83	2.88
Root length (cm)	18.89	17.12
Root weight (gm)	108	107.2
Proportion of small size roots (%)	32.67	67.22
Proportion of cracked roots (%)	0.22	1.89
Proportion of forked roots (%)	2.56	6
Proportion of hairy roots (%)	8.33	12.67
Proportion of twisted roots (%)	17.56	25.22
	Root yield (t ha-1)	
Research field	52.65	47.26
	Farmers' field	
Marketable root yield (t ha-1)	42.52	36.99
Total root yield (t ha-1)	48.17	45.52
Seed yield (g/plant)	5.87g per plant	5.25g per plant
Release year	2014	
Breeder/Maintainer	Harmaya University	

The influence of temperature on root growth and performance of carrot was reported by Rosenfeld. Carrot is classified as a cool-season crop, the minimum temperature for growth being 5°C and the optimum temperature being 18°C-25°C. Rosenfeld grew carrots at constant temperatures of 9°C, 12°C, 15°C, 18°C and 21°C and observed the highest root weight at 12°C and 15°C. According to Rubatzky, above 25°C the increased rate of plant respiration tends to limit root yields in carrot.

Flowering characters

Plants at lower population density gave the highest number of secondary and tertiary umbels and their number decreased with increasing planting density. 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 indicated the decreased number of umbels per plant with increasing plant density. The size of umbels and the number of umbellets per umbel of each order (primary, secondary and tertiary) were significantly different among planting dates. 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,

Table 2: Root and seed yield of first and second generation Nantes carrot grown at Ankober during 2004 and 2005/2006.

Carrot	2003/2004		2005/2006	
	Local 1st generation	Imported	Local 2nd generation	Imported
Root yield (q/ha)	175.42	153.9	181.7	215
Root length (cm)	13.07	12.27	16.07	15.8
Root diameter (cm)	3.67	3.4	3.44	3.61
DM (%)	9.06	11.42	10.01	12
Number off types	3	0	0.67	0.68
Cortex–core ratio	-	-	2.25	1.97
Seed yield (gm-2)	8.04	2.91	4.43	3.82

Table 3 : Carrot production in Ethiopia from 2004/2005 to 2010/2011.

Carrot production in Ethiopia from 2004/2005 to 2010/2011 Year	No of holders	Area (ha)	Production (t)	Productivity (t/ha)
2010/2011	117649	2214.9	12345.8	5.6
2009/2010	157032	2712.7	18229.3	6.7
2008/2009	205637	2100	13466.6	6.4
2007/2008	149484	1400	10000	7.1
2006/2007	137052	946.7	6694.1	7.1
2005/2006	134358	1071.2	6881.5	6.4
2004/2005	138208	1741	17.9	10.3

substances known to enhance flowering characters in low temperatures. November and December plants' long-exposure to low temperature might have led to better flowering characters, as exhibited in umbel size (diameter) and a number of umbellets per umbel than January and February plants. Quagliotti observed that at lower temperatures increased number of flowers per umbellet and number of umbellets per umbel [15]. Ghoname found that carrot seed treated with GA gave the simplest results with reference 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 usually triggered by low temperatures.

High rainfall may need resulted in flower abortion and therefore the occurrence of diseases during flowering of the later plantings. Ogawa noticed that flowering and seed set of carrot were significantly reduced where under continuous rainfall. Flowering characteristics expressed as umbel size and number of umbellets, were observed to say no progressively alongside the respective planting dates. Besides, the population and effectiveness of pollinating insects may need an impression on seed yield of carrot [16].

Seed quality parameters

The term seed quality encompasses several attributes of seeds among which Thousand Seed Weight (TSW), germination percentage, viability capacity and germination rate were used in this seminar. Thousand seed weight, germination percentage and germination rate were significantly different among the planting dates. Likewise, germination percentage and rate were significantly higher and faster for November plants 80.8% and 6.8 days, respectively 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. Seeds with high germination percentage had short mean germination time as a result indicated on the association between germination percentage and mean germination rate. Nevertheless, in the range of plant in densities used in the study, these quality parameters did not show any significant differences, implying that sowing date are more important in affecting seed quality than planting density. Studies reported by Kong exhibited that high density increased the seed yield per unit area without significant effects on seed quality [17].

Disease incidence and severity

The severity of Alternaria leaf blight was significantly different among the different planting dates and planting densities showing that the incidence and severity of the disease increased significantly with a delay in planting. The occurrence of the disease appeared to be related with the weather pattern particularly to rainfall. Rubatzky reported that rain and sprinkler irrigation favor the event of Alternaria blight and its incidence further increased with high humidity and temperatures of 14°C-35°C. Therefore, as indicated within the weather data the weather, particularly the rainfall and therefore the ratio during flowering and seeding late in January to February appeared 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 blight [18]. The decline in yield of the later plants might be thanks to the incidence of Alternaria blight which was observed to occur late after the onset of the rain and whose severity was far more pronounced in narrowly spaced row plants. The disease is reported to cause a big yield loss in carrots. Among the expected diseases for carrot, Alternaria blight (*Alternaria dauci*), plant disease (*Alternaria radicina*) and Carrot bacterial blight (*Xanthomonas carotae pv. Carotae*) are the major ones. The released variety (Haramaya I) and other selections were evaluated for these and other diseases and bug pest. No pesticide was applied during the evaluation of the variability ranging from the initial screening to verification. However, it's not been observed the symptom of anybody of the main diseases [19,20].

Seed yield and yield components

The main effects of sowing dates and planting densities as well as their interaction significantly affected seed yield, the seed yield per plant and per hectare decreased significantly with a delay in planting. In delayed planting umbel diameter and numbers of umbellets per umbel and seed weight per umbel were significantly less which could have inevitably reduced the seed yield. Likewise, increasing planting density noticeably decreased the mean seed weight per umbel of each order. Thus, increasing the plant density decreased the mean seed weight per plant. Who reported increased plant spacing increased seed weight per umbel [21-23].

Increased seed yield per plant with increase plant to plant distance. This could flow from to less effect of competition among plants for growth resources like water, nutrient, light, oxygen and CO^2 and in pollinating agents. 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 can flow from to their smaller size and fewer time available to develop [24,25].

It was also reported that, as planting density increased, there's a discount within 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 may need resulted in higher total yield. Carrot seed yield (kg/ha) normally increase with plant population.

Conclusion

Many researchers written and reported that the results of all the evaluated parameters were significantly affected either by sowing date or plant density or by both except for days to emergence. Plant height, umbel size (diameter), number of umbellets per umbel, thousand seed weight, germination percentage and rates are not showed a significance difference on plant densities. Similarly, sowing dates did not influence the number of primary and secondary branches per plant.

As I deduced that identifying the appropriate sowing dates and planting density that would help to optimize the yield and quality of carrot seed production. 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, and number of umbels per plant, number of umbellets per umbel and seed weight per umbel. Using of the recommended inter rows spacing for both seed-to-seed and root-to-seed carrot production methods 20 cm-30 cm and 50 cm-75 cm respectively, is important to reduce the incidence and severity of *Alternaria* leaf blight resulted in irrigation and delayed harvesting.

In conclusion, carrot seed production and productivity affected by various factors among them a right time of sowing and optimum plant density with a correct quality cultivar have a vital role.

Recommendation

It recommended for farmers to use *Harmaya I* variety for sustainable production and productivity interms of yield and quality of carrot seed. It has a good resistance capacity of disease and insect pests, and high quality and high yield potential of seed and root production.

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