EFFECT OF SPACING AND SOWING TIME ON THE GROWTH AND YIELD OF CARROT (*Daucus carota* L.)

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DECEMBER 2006

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BY

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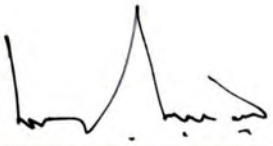
REGISTRATION NO. 25206/00332

A Thesis
Submitted to the faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE
IN
HORTICULTURE AND POSTHARVEST TECHNOLOGY

SEMESTER: JULY- DECEMBER 2006

Approved by:



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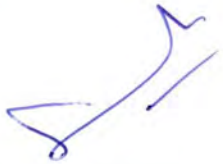

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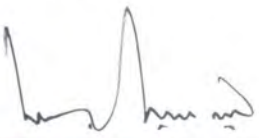
This is to certify that the thesis entitled, "**EFFECT OF SPACING AND SOWING TIME ON GROWTH AND YIELD OF CARROT (*Daucus carota* L.)**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **HORTICULTURE AND POSTHARVEST TECHNOLOGY**, embodies the result of a piece of *bona fide* research work carried out by MD. ASHRAFUL KABIR Registration No. 25206/00332 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.



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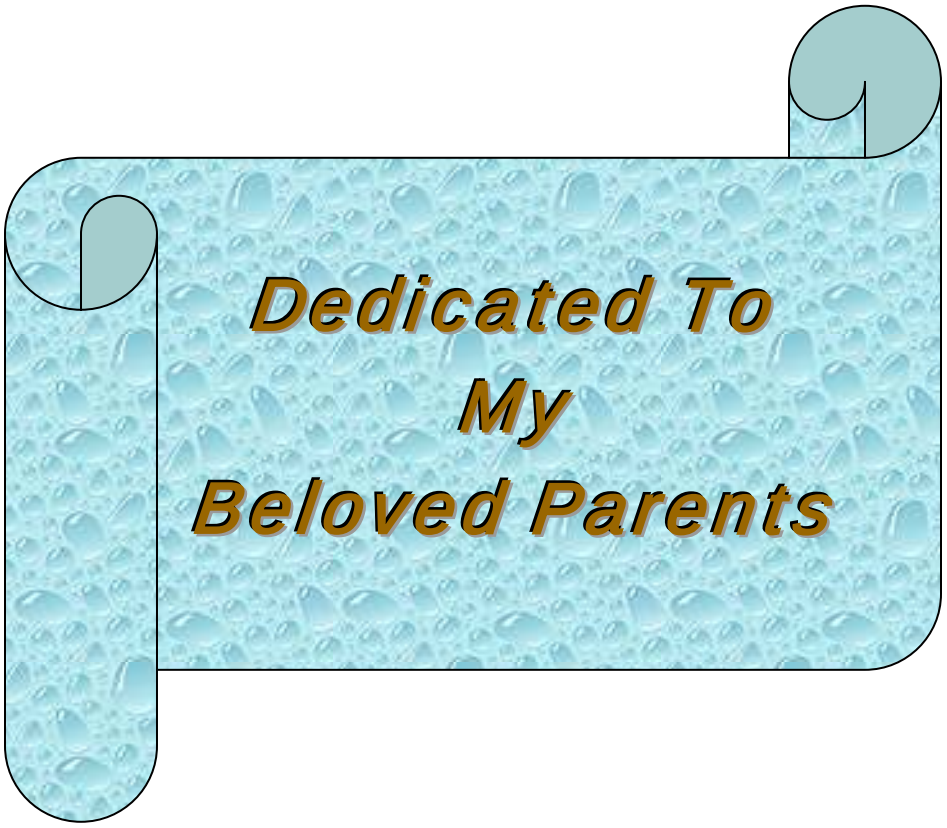
Dedicated To
My
Beloved Parents

ACKNOWLEDGMENT

Bismillahir Rahmanir Rahim. All Praise are due to the Almighty and merciful Allah, the supreme ruler of the universe, whose infinite mercy enabled the author to pursue his education in agriculture and to complete the degree of master of Science in Horticulture and Postharvest Technology and for guiding him towards the right path of Islam. The author wishes to express his heartiest gratitude and profound respect to his honorable teacher, Research supervisor, professor A.K.M. Mahatabudddin, Department of Horticulture and Postharvest Technology, Sher-e-bangla Agricultural University (SAU), Dhaka-1207 for his intellectual guidance, scholastic supervision, valuable instruction, constructive criticism, encouragement and generous assistance throughout the whole period of research and preparation of this manuscript as well as development his career for further betterment. Heartiest thanks to his co-supervisor, Md. Hasanuzzaman akand, Assistant professor, Department of Horticulture and Postharvest Technology, SAU, Dhaka-1207 for his co-operation, constructive suggestions to conduct the research work as well as preparation of the manuscript. The author wishes to express his heartiest gratitude to his reverend teacher professor Md. Ruhul Amin, Chairman, Department of Horticulture and Postharvest Technology, SAU, Dhaka-1207 The author also like to express his heartiest respect to Dr. Md. Nazrul Islam, Associate Professor, Department of Horticulture and Posharvest Technology in Sher-e-Bangla Agricultural University, Dhaka for his constrictive criticism, helpful advice, valuable suggestions and generous help to improve the manuscript. The author expresses his sincere respect to Md. Humayun Kabir, Assistant Professor, Md. Jahidur Rahman, Assistant professor, Arfan Ali, Lecturer and Jasim Uddain Lecturer, department of Horticulture and Posharvest Technology SAU Dhaka for their inspiration, constructive criticism and comments in preparing the manuscript. *The author would like to thank all of his course mates especially Polash, Zubel, Dablu, Kamal, Anowar, Rony, Rezaul, Giny, Jony, Shimu, Tithi and Yamin to cooperate and help during the research work. The author intends to extend his cordial indebtedness to his beloved parents, Mrs. Rashida Begum, and Md. Akmal Hossain for their blessing, sacrifice and inspiration throughout his life.The author also like to thanks all of his relatives, friends and all well wishers for their inspiration and blessing without which this study would here been impossible*

December 2006

The Author

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LIST OF ACRONYMS

Full Word	Abbreviation
Abstract	Abst.
Agronomy	Agron.
Agriculture	Agric.
Agro- Ecological Zone	AEZ
At the rate of	@
Bangladesh Agriculture University	BAU
Bangladesh Bureau of Statistics	BBS
Bangladesh Agricultural Research Institute	BARI
Bangladesh Institute of Nuclear Agriculture	BINA
Bangladesh Rice Research Institute	BRRI
Benefit Cot Ratio	BCR
Centimeter	cm
Cultivar (s)	cv.
Days after Sowing	DAS
Degree Centigrade	^{0}C
Dry Matter	DM
Dry Weight	DW
Duncane's Multiple Range Test	DMRT
et alii (and others)	*et el.*
Etcetera	etc.
Food and Agricultural Organization	FAO
Figure	Fig.
Fresh Weight	FW
gram (s)	g
Horticulture	.Hort.
Journal	J
Kilogram (s)	kg
Kilogram per hectare	kg/ ha

Least Significant Difference	LSD
Meter	m
Full Word	**Abbreviation**
Muriate of Potash	MP
Namely	Viz.
Number	No.
Non significance	NS
Hydrogen ion concentration.	pH
Phosphorus	P
Potassium	K
Percentage	%
Randomized Complete Block Design	RCBD
Relative Humidity	RH
Research	Res.
Science	Sci.
Society	Soc.
Sher-e-Bangla Agricultural University	SAU
Soil Resource and Development Institute	SRDI
Taka	Tk
That is	i.e.
Triple Super Phosphate	TSP
Ton per hectare	t/ ha

EFFECT OF SPACING AND SOWING TIME ON GROWTH AND YIELD OF CARROT (*Daucus carrota* L.)

ABSTRACT

An investigation was carried out at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2005 to April 2006 to determine the growth and yield of carrot as influenced by different sowing dates and spacing. The study was conducted with four sowing times of carrot viz. 28 November (T_1), 8 December (T_2), 18 December (T_3) and 28 December (T_4) having three spacings viz. 20cm x 10cm (S_1), 25cm x 15cm (S_2) and 30cm x 20cm (S_3). Leaf length, root length, leaf fresh weight, root fresh weight, root diameter, leaf dry weight and root dry weight were significantly differed among the sowing times at different spacings. All the yield contributing characters were the highest to the plants grown on 28 November at the spacing of 30cm x 20cm and the lowest on 28 December at the spacing of 20cm x 10cm. The maximum root length (14.82 cm), root diameter (20.39 cm), root fresh weight (217.4 g/plant) and root dry weight (32.47 g/plant) were found in T_1S_3 and the minimum of these parameters were found in T_4S_1. The percentage of cracking root and branched root of carrot was lower in T_1S_1 followed to others and it was gradually increased due to delay sowing. The maximum gross yield (38.17 t/ha) was found in T_1S_1 and the minimum (6.65 t/ha) was in T_4S_3. The maximum (34.33 t/ha) and the minimum (3.135 t/ha) marketable yield were also found in the treatment of T_1S_1 and T_4S_3. The highest (2.95) Benefit Cost Ratio (BCR) was observed in T_1S_1 and the lowest (-0.03) was in T_4S_2. The yield and yield contributing characters were increased with the closest spacing but growth parameters were increased with the widest spacing. Gross yield and marketable yield were increased in early sowing and decreased in delay sowing. In twelve treatments of combination of four sowing times and three spacings, the maximum yield and marketable yield were in T_1S_1.

INTRODUCTION

Carrot (*Daucus carota* L.), herbaceous biennial plants, belongs to the genus *Daucus,* species *Daucus carota* L. and the member of Apiaceae family (Peirce, 1987). It is said to be originated in Mediterranean region (Banga, 1976). It produces an enlarged fleshy tap root that is edible and possesses high nutritive value (Shanmugavelu, 1989).

Carrot is mainly a temperate crop grown during spring through autumn in temperate countries and during winter in tropical and subtropical countries of the world (Bose and Som, 1990). According to Barnes (1936), 15.6 ^{0}C to 21.1^{0}C temperature is the ideal for its growth and development. Higher and lower temperatures reduce the rate of growth and adversely affect the quality of the roots. Carrot grows successfully in Bangladesh during Rabi season when temperature ranges from 11.17 ^{0}C to 28.9 ^{0}C (Alim, 1974) and the best time is from mid November to early December for its cultivation to get satisfactory yield (Rashid, 1993).

Vegetables are one of the most important components of human food, which provides proteins, carbohydrates, fats, vitamins and minerals. Per capita vegetable production in Bangladesh is much less than its requirement. It contains high amount of carotene (10 mg/100g), thiamin (0.04 mg/100g), riboflavin (0.05mg/100g) and also serves as a source of carbohydrate, protein, fat, minerals, vitamin-C and calories (Yawalker, 1985). Sugar and volatile terpenoids are the two major components of carrot flavor; glucose, fructose and sucrose which make up more than 95% of the free sugars and 40% to 60% of the stored carbohydrates in the carrot root. The ratio of sucrose to reducing sugar increases with root maturity but decreases following harvest and

during cold storage (Freman and Simon, 1983) (Appendix II). Blindness in children for the severe Vitamin-A deficiency is a problem of public health in some countries, particularly in the rice dependent countries of Asia (Woolfe, 1988). So, carrot (rich in Vitamin-A) may contribute a lot of Vitamin-A to overcome this situation in Bangladesh,

The popularity of carrot is increasing day by day in Bangladesh especially among the urban people because of its high nutritive value and possible diversified use in making different palatable foods. Carrot can be eaten either row or by making halua, a preparation of sweets in Bangladesh. Carrot root is being used as vegetable for soups and curries and grated roots are used as salad. It can be canned (Chauhan, 1989). But large-scale production of carrot is yet not started to meet up the demand. The area under carrot cultivation was 899 thousand hectares with total production of 193740 thousand tones in the world (FAO 2000). In Bangladesh the production statistics of carrot is not available. Rashid (1993) mentioned an average yield of carrot 25 tonnes per hectare. The production is relatively low compared to other carrot producing countries, Switzerland, Denmark, Sweden, UK, Australia and Israel, where the average per hectare yield are reported to be 40.88 - 42.67, 51.88, 54.88, 56.70 and 64.20 tonnes respectively (FAO, 2000).

Plant spacing is one of the important factors for the increased production of carrot. Pavlek (1977); Lipari (1975) and McCollum *et al*. (1986) reported that there is a positive correlation between the number of plants and yield of carrot. But many workers reported that different plant

densities of spacing have different effect for the marketable yield of carrot (Dragland, 1978; Nogueira *et al*. 1982).

Sowing time is also an important factor for increasing yield of carrot (Rashid and Shakur 1986). The different sowing time of carrot have a significant effect on growth and yield due to environmental factor like temperature and light intensity (Mack, 1977) suggested that carrot should be harvested at proper stage of maturity. Otherwise, it will become fluffy and unfit for consumption. Moreover, the percent of root splitting, firmness, the contents of dry matter, carotene and sucrose are increased during the growth of carrot, whereas the contents of glucose and fructose and respiration quotient are decreased. The contents of total sugar remained almost constant from the beginning of the harvesting period but increased at low temperature.

To extend the availability of carrot during the early and late period of growing season and sowing time may play a critical role. Also quality of the roots depends on the harvesting time under Bangladesh condition. There is also a significant interaction between plant spacing and sowing date (Salter *at al*. 1979).

Therefore the present investigation was taken for the following objectives:

i) To find out optimum sowing time for better yield

ii) To estimate the effect of spacing on the growth and yield of carrot.

iii) To study the interaction effect of spacing and sowing time on growth and yield of carrot.

REVIEW OF LITERATURE

Carrot (*Daucus carrotta* L.) is one of the most important vegetable crops of the world. From the nutritional point of view, it received much attention to the researchers throughout the world to develop its production technology. Many research works have been carried out in relation to the effect of sowing dates and different spacing for the production of marketable size and maximizing the yield and quality of carrot in different countries. Yet, a few studies were found to have made in this regard in Bangladesh. However, literatures available in this respect at home and abroad were presented here.

2.1. Effect of sowing dates on the growth and yield of carrot

Pariari and Maity (1992) were conducted an experiment on three carrot cultivars (Pusa Meghali, Pusa Kesar and Half Long Nantes) evaluated for 9 growth and yield-related traits when grown under 4 sowing dates (14 October to 28 November) at Mondouri, West Bengal during 1988. Significant differences were observed due to both cultivars and sowing dates. Pusa Kesar was superior to the other cultivars, having larger roots of increased weight and producing a mean yield of 1.7 t/ha. Top weight, root weight and root yield were significantly higher after sowing on 29 October. The greatest yield (2.8 t/ha) was obtained when Pusa Kesar was sown on 29 October.

Jaiswal,-M-D *et al.* (2003) conducted an experiment on sowing date (20 July, 10 August, 30 August, 19 September or 9 October) and spacing (45x15, 45x20, 45x30 or 45x45 cm) of carrot (cv. Pusa Kesar) in Akola, Maharashtra, India, during kharif 1998/99. Early sowing (20 July) obtained the tallest plant height (156.25 cm) at 150 days after sowing and maximum number of leaves per plant (34.66) at 150 DAS Plant height at 150 DAS, which increased with the reduction in spacing, was greatest (147.42 cm) at a spacing of 45x15 cm; this spacing also gave the lowest number of days to (131.26) flowering.

Hoque and Bhuyan (1983) conducted an experiment with five different varieties of carrot viz. Nantes Superior, Scarlet Nantes, Danvers, 126, Chantenay Red Core and Imperator 58 with a view to find out the optimum harvesting date for maximum yield of any particular variety. Among the varieties, Danvers 126 gave the highest yield (59.2 t/ha) at 126 days after sowing and then the yield decreased. The other three varieties, Imperator 58, Scarlet Nantes and Chantenay Red Core Show the same trend. The only exception in this regard was Nantes Superior who showed increase in yield up to 111 days after sowing with a gradual decrease as the days is increased. They further noted that carrot should be harvested at 110 to 125 days after sowing for obtaining the highest yield and good quality roots.

Vulsteke and Bockstaele (1975) studied three years trials with celeriac planted on three dates in May/June and harvested on three dates from mid-November. The highest yields were obtained with late harvesting that also favored quality.

Mason and Tong (1971) conducted an experiment in HongKong and compared twelve carrot cultivars in 2 trials planted in October and January. They observed that when plated earlier, the best cultivars yielded three times more, and the poorest six times, The best yielders in both trials were Dande Crop, Market King, Hawkes, All seasons, Kunella strong Top, Osborne park and champion.

Shantha-Nagarajan; Pandita-VK; Deepti-Sharma; Nagarajan-S and Sharma-D (1998) carried out an experiment and reported that carrot cv, Pusa Kesar seeds both the sowing environment and umbel order affected field emergence and vigor. The first environment i.e. September sowing (mean maximum and minimum temperatures of 32.0 and 22.6^{0}C, respectively) combined with seeds from primary umbels gave the best performance.

Ilic-Z conducted an experiment on the influence of sowing time and growing space on the possibility of producing carrot seeds through the "seed-seed" system. In experiments in Kosovo and Metohija, seed yield per plant of carrot cv. Nantes was highest (22.7 g/plant) from the first sowing date (28 July) and at the greatest spacing (25 X 25 cm) with 12 primary and 35

secondary and tertiary flowers. At the narrowest spacing (25 X 10 cm) and sowing on 18 August seed yields were only 7.3 g/plant with 1 primary and 5 secondary flower. Total seed yields were highest (2948 kg/ha) from sowing on 28 July at a spacing of 25 X 10 cm. Seed germination was >90%.

Berry-NA; Wratten-SD and Frampton-C conducted an experiment on the effects of sowing and harvest dates on carrot rust fly (Psila rosae) damage to carrots in Canterbury, New Zealand. The effects of manipulating sowing and harvest dates on the degree of carrot rust fly (*Psila rosae*) damage on carrots (*Daucus carota*. L) was investigated at Lincoln University, Canterbury, New Zealand in 1994-95. The proportion of damaged carrots resulting from late sowings (mid November-late December) and harvested before the third carrot rust fly generation was lower than those sown earlier (early-late October). However, a reduction in growing time for later sowing dates resulted in roots, which were not of a marketable size. There were low numbers of first-generation flies caught from early November to late December, and very high numbers of third-generation flies caught from late March to late June. An early sowing (October) in combination with a harvest before the peak of third-generation flight activity (mid April-early May) resulted in a higher proportion of marketable carrots.

Pashine-YP; Deshmukh-PP; Diware-DV; Deshmukh-SV and Uke-PC conducted an experiment on the effect of sowing time on the yield of carrot (*Daucus carota* Linn.) in Punjab Krishi Vidyapeeth, India. In this experiment, Seeds of Pusa Kesar, Nantes and local cultivars were sown on 7 different dates from 5 Nov. 1988 to 5 Feb. 1989, at fortnightly intervals. Maximum yield (155.18 q/ha) was obtained by early sowing on 5 Nov., followed by sowing on 20 Nov. (144.81 q/ha). Yield decreased with delayed sowing. The local cultivar produced the highest root yield (152.40 q/ha), followed by Pusa Kesar (102.96 q/ha).

Pariari-A and Maity-TK conducted a field trail in title on Growth and yield of carrot (*Daucus carota* L.) cultivars as influenced by sowing dates. In this experiment three carrot cultivars (Pusa Meghali, Pusa Kesar and Half Long Nantes) were evaluated for 9 growth- and yield-related

traits when grown under 4 sowing dates (14 October to 28 November) at Mondouri, West Bengal during 1988. Significant differences were observed due to both cultivars and sowing dates. Pusa Kesar was superior to the other cultivars, having larger roots of increased

2.2. Effect of spacing on the growth and yield of carrot

Muhammad-Amjad and Anjum-MA (2001) had set up an experiment on the effect of root size, plant spacing and umbel order on the quality of carrot seed in University of Agriculture, Faisalabad-38040, Pakistan. They observed that the 1000-seed weight, seed moisture content, plant height, root length and fresh and dry weights of seedlings harvested 10 days after germination were not significantly affected by the root size. Plant spacing had significant effects on 1000-seed weight, root length and fresh weight of seedlings. Wider spacing (45 cm) proved better compared with close spacing. However, seed moisture content, seed germination, plant height and dry weight of seedlings after 10 days of germination had no significant response to plant spacing.

Taivalmaa-SL and Talvitie-H (1997) studied in a field experiments on the effects of ridging, sowing rate and sowing system on the yield and visible quality of carrots (cv. Fontana BZ) in W. Finland in 1990-92. The highest yields were recorded for carrots sown in double rows on a narrow ridge. The effect of sowing system on mean root weight differed depending on the ridging regime. The mean weight of roots was higher for carrots cultivated on broad ridges than in other systems. Sowing rate had the most significant effect on mean root weight. For industrial purposes it is recommended that carrots be cultivated on broad ridges in double rows at low sowing rates with irrigation. The optimal cultivation technique for carrots destined for the fresh vegetable market would be narrow ridges sown in double rows at high sowing rates. The ridging system, sowing rate and row spacing did not appear to affect the external quality of roots.

Noguera *et al.* (1982) conducted an experiment in Brazil to find out the effect of plant spacing on yields of carrot (*Daucus carota L.*) cv. Kuroda Nacional. They thinned carrots to spacing of

20 cm x 5 cm, 20 cm x 8 cm, 20 cm x 10 cm and 20 x 15 cm which produced total yields of 14333.3 kg/ha, 12539.7 kg/ha, 11920.6 kg/ha and 12079.4 kg/ha respectively. Average root weight was increased from 55.53 kg/plot to 128.43 kg/plot as spacing was increased but it was significantly higher at the greatest spacing.

Warne (1952) made an investigation and reported that the optimum plant density for carrot was between 60 and 100 plants per square meter. The general conclusion from this trial was that visual inspection of a root crop could lead to an unnecessary fear of overcrowding; about 10% of the crop must in practice be too small if the crop as a whole was to give its maximum yield

Nilsson and Hintze (1952) conducted trials with 8 varieties and strains of carrot at 7 localities in Sweden from 1948 to 1950. Each consisted of 4 or 8 blocks randomized in a split plot design. Heavier yields obtained in 5cm spacing than 10 cm; in two Southern localities where unthinned plots were compared with 5 cm spacing, the former gave the higher yield.

Goodman (1953) found from an investigation that wide spacing showed a depressing effect on yield with the increased percent of pitted and course roots.

Wagner and Benes (1955) from one of their experiments reported that a spacing of 25 cm x 5 cm had produced the highest yield of seven carrot varieties. In another experiment they noticed that a spacing of 30 cm. x 5 cm was the best. They concluded that the highest yield and the best quality were associated with the greatest distance between the rows and the smallest distance within the row.

Ward (1959) conducted an experiment for two years with Top Weight variety of carrot. He grew the carrots with several spacing, starting form 2.54 cm to 17.78 cm within the rows. Spacing at 7.62 cm gave the highest number of large carrots. Spacing at 5.08 cm had the greatest yield of medium number and medium graded carrots.

Bleasdale *et al*., (1961) reported that employing a 17.78 cm in row-row spacing with about 112 plants per square meter increased the mark table yield of carrot.

Frohlich *et al*., (1971) conducted an experiment and reported that total and marketable yields of late carrot were increased as a result of reduction in row spacing from 27 cm to 25 cm. Increasing plant density enhanced the marketable yield more than the total yield.

Jedlickova *et al*., (1971) planted carrot seeds of Nantes variety at the distance of 3.5 and 7 cm apart within rows and of 22.5 cm, 30.0 cm and 37.5 cm apart between rows. The highest yields were obtained from the spacing of 3 cm x 22.5 cm or 3 cm x 30.0 cm.

Bussell (1975) studied the effect of plant densities on the yield of small (13 to 18 mm diameter, 7.5 to 11.5 cm long) finger carrots ranging from 533 to 2500 seeds per square meter in two experiments. He obtained the highest yield from the highest densities used in both the experiments.

Lipari (1975) worked with three plant densities (50, 75 and 100 plants per square meter) and two rows spacing (20 cm and 40 cm) of carrot and found a significant correlation between the yield of marketable roots and plant density. He observed that yield was increased by the higher density of plants in the row, the number of root increased but single weight of marketable root decreased.

Bussell (1976) worked with spacing on baby carrots sown on three different dates from mid September to mid-December under New Zealand conditions. He reported that the optimum population at harvest was about 13000 plants/m^2. Root length decreased as the plant population increased. Again Bussell (1978) arranged another experiment on the production of baby carrot and showed the same result.

Lucchesi *et al.*, (1976) studied with the radish cv. Early Scarlet Globe. The plants were spaced within the row at 4 and 8 cm with 5 cm, 10 cm, 15 cm and 20 cm between rows. They obtained the highest commercial yield (375 g/0.5 m^2) from plants spaced at 15 cm x 8 cm.

Pavlek (1977) studied three years trial with 15 carrot cultivars to investigate the effects of plant density on yields under Yugoslavia condition. He found a positive correlation between the number of plants and yield per hectare.

Dragland (1978) conducted an experiment of the yield and quality of carrots at different plant densities in Norway. He noticed that in general both the total and the marketable yields increased with increasing plant density. Root size was decreased with increasing plant density but the number of splitted of branched roots was not significantly affected by the plant spacing.

Kepka *et al*., (1978) in a small scale field experiment found that total as well as marketable yield of carrots rose with decreasing inter-row spacing from 45 cm to 10 cm and intra-row spacing from 6 cm to 2 cm. A population of 111 of 222 plants/m^2 produced the highest and most uniform yield.

Mack (1979) Reported after an investigation that total root yields as well as roots of 25 mm and 38 mm in diameter were increased in carrot cv. Red cored and Chantenay as row spacing was reduced from 60 cm to 15 cm under New Zealand condition. Difference within row spacing did not have a significant impact on total yield but affected yield of various size grades. In general the root length was decreased as the plant population increased.

Salter *et al*., (1979) in U. K reported that total root yield was not significantly affected by plant arrangement on plant density in most cases. However, the yield of canning size roots (20-30 mm diameter) was influenced by plant density. With the lowest density treatments, the highest yield of canning roots was obtained form the earliest harvest. Mean root weight was significantly affected by density.

Noguera *et al.* (1982) conducted an experiment in Brazil to find out the effect of plant spacing on yields of carrot (*Daucus carota L.*) cv. Kuroda Nacional. They thinned carrots to spacing of 20 cm x 5 cm, 20 x 8 cm, 20 cm x 10 cm and 20 cm x 15 cm which produced total yields of 14333.3 kg/ha, 12539.7 kg/ha, 11920.6 kg/ha and 12079.4 kg/ha respectively. Average root weight was increased from 55.53 kg to 128.43 kg as spacing was increased but was significantly higher at the greatest spacing.

Farazi (1983) conducted an experiment on the effect of plant spacing on the yield of carrot under Bangladesh condition. He found that the closest spacing (18 cm x 8 cm) produced significantly higher yield over wider spacing.

Snoek (1984) worked on the relationship between plant density and yield in Netherlands. He found that the optimum density was about 500 plants/m^2.

Dragland (1986) carried out an experiment in Norway on carrot sown in May. He thinned out seedlings to give densities of 45, 70 or 90 plants/m^2. He found that at the first harvest on 1 September, the highest salable yield (29 ton/ha) was achieved with a density of 70 plants/m2 and at 2nd harvest on 10 October, the highest salable yield (42 ton/ha) was achieved with a density of 90 plants/m^2

Mccollum *et al.* (1986) conducted an experiment in USA to evaluate the response to densities of 39, 59 or 79 plants/m^2. They found that marketable and total yields increased linearly with increased plant density from 24 to 85 plants/m^2. Mean length and diameter of marketable roots were decreased linearly with increased plant density.

Wiebe (1987) grew carrots at densities ranging from 350 to 1200 plants/m^2. He found that a density of 400-500 plant/m^2 was optimum for early harvest but 600-700 plants/m^2 gave higher yields of marketable roots at late harvest.

Bussell and Dalenger (1972) worked on carrot cvs. planted in October in New Zealand and harvesting was done at weekly interval beginning 10 weeks from planting time. The roots were assessed for color determined as mg carotene/100 g dry matter. Eleven cvs. were appeared unsuitable for baby carrots (i.e. 7.5-12.5 cm long and 2.50/5-7.5/10.0 cm diameter) production for reasons of low yield of poor color. The remaining 10 cvs. together with Manchester Table were grown in further sown in mid-January and harvested in late March and April. Yields were lower than in the first trial but the cvs. s754, Grenadier, Amsterdam Finger, Amsterdam Elson, Amsterdam Forcing, Tiny Tot, B52 and continental were considered to be suitable in New Zealand.

Fritz and Habben (1977) sowed the seeds of four carrot cvs. in green house condition under German Federal Republic conditions where the root were harvested 71, 99 of 127 days later. Seeds of eight cvs. were sown in the open condition and roots were harvested 96, 132, 173 or 208 days later. They suggested that carrot should be harvested at proper stage of maturity; otherwise it will become fluffy and unfit for consumption. Moreover, the percent of root splitting, firmness, the contents of dry matter, carotene and sucrose are increased during the growth of carrots, whereas the contents of glucose and quotient are decreased. The contents of total sugars remained almost constant from the beginning of the harvesting period but increased at low temperatures in late autumn.

Salter *et al.,* (1979) found in an investigation that root yield of carrot was affected by harvesting time. They obtained the highest absolute yield from the latest harvest, while the highest yield of canning roots (20-30 mm diameter) was obtained from the earlier harvests.

Hoque and Bhuyan (1983) conducted and experiment with five different varieties of carrot namely, Nantes superior, Scarlet Nantes, Danvers 126, Chantenay red cored 5 and Imperator 58 at BARI, Joydebpur, during the winter of 1981-1982 with a view to find out the optimum time of harvest for maximum yield of any particular variety. Among the varieties, Danvers 126 gave

the highest yield (59.2 t/ha) after 126 of sowing. They further noted that carrot should be harvested within 110 to 125 days of sowing for obtaining the highest yield of good quality roots.

Rashid *et al.*, (1986) carried out an experiment and reported that the roots of carrot continued to increase in size until harvested 135 days after sowing. They suggested that for getting higher total yield and early yield, the crop should be sown as early as possible in the Rabi season. They also found that in case of cultivar Nantes, harvesting of roots as baby carrots is possible 75 days after sowing.

MATERIALS AND METHODS

3.1. Experimental site

The experiment was conducted at the Horticulture Farm of the Sher-e-Bangla Agricultural University, Dhaka during November 2005 to April 2006. Laboratory works were done both at Horticulture Laboratory and Soil Science Laboratory in Sher-e-Bangla Agricultural University, Dhaka-1207.

3.2. Climate

The experimental area is situated in sub-tropical climatic zone as characterized by heavy rainfall during the month of April to September and scanty rainfall during the rest period of the year (Anonymous, 1960). Information regarding monthly maximum and minimum temperature (^{0}C), rainfall (cm) and relative humidity (%) were recorded from the Weather Yard Station, Agargaon, Dhaka during the study period.

3.3. Soil

The experiment area was belonged to the Modhupur Tract and AEZ 28 (FAO, 1971). The soil was sandy loam with a pH value 6.6. Soil samples were collected randomly from a depth up to 30 cm of the experimental plot and analyses were done and showed nitrogen 0.075%, phosphorus 13 ppm, exchangeable potassium 0.20 me/100g soil and organic carbon 0.82%.

3.4. Experimental materials

New Caroda, variety of carrot, was used for the experiment. The seeds of this variety were collected from "Hamid Seed Store", Siddique Bazar, Dhaka.

3.5. Experimental Treatments

The experiment was conducted to study the effect of four levels of sowing times and three levels of spacing. Different levels of two factors were as follows:

Factor A:

Sowing time: Carrot seeds were sown at four different times denoted as T_1, T_2, T_3 and T_4:

T_1= 1st sowing, November 28, 2005

T_2= 2nd sowing, December 08, 2005

T_3= 3rd sowing, December 18, 2005

T_4= 4th sowing, December 28, 2005

Factor B:

Spacing: Three different spacing were used denoted as S_1, S_2 and S_3

S_1= 20 cm × 10 cm

S_2= 25 cm × 15 cm

S_3 = 30 cm × 20 cm

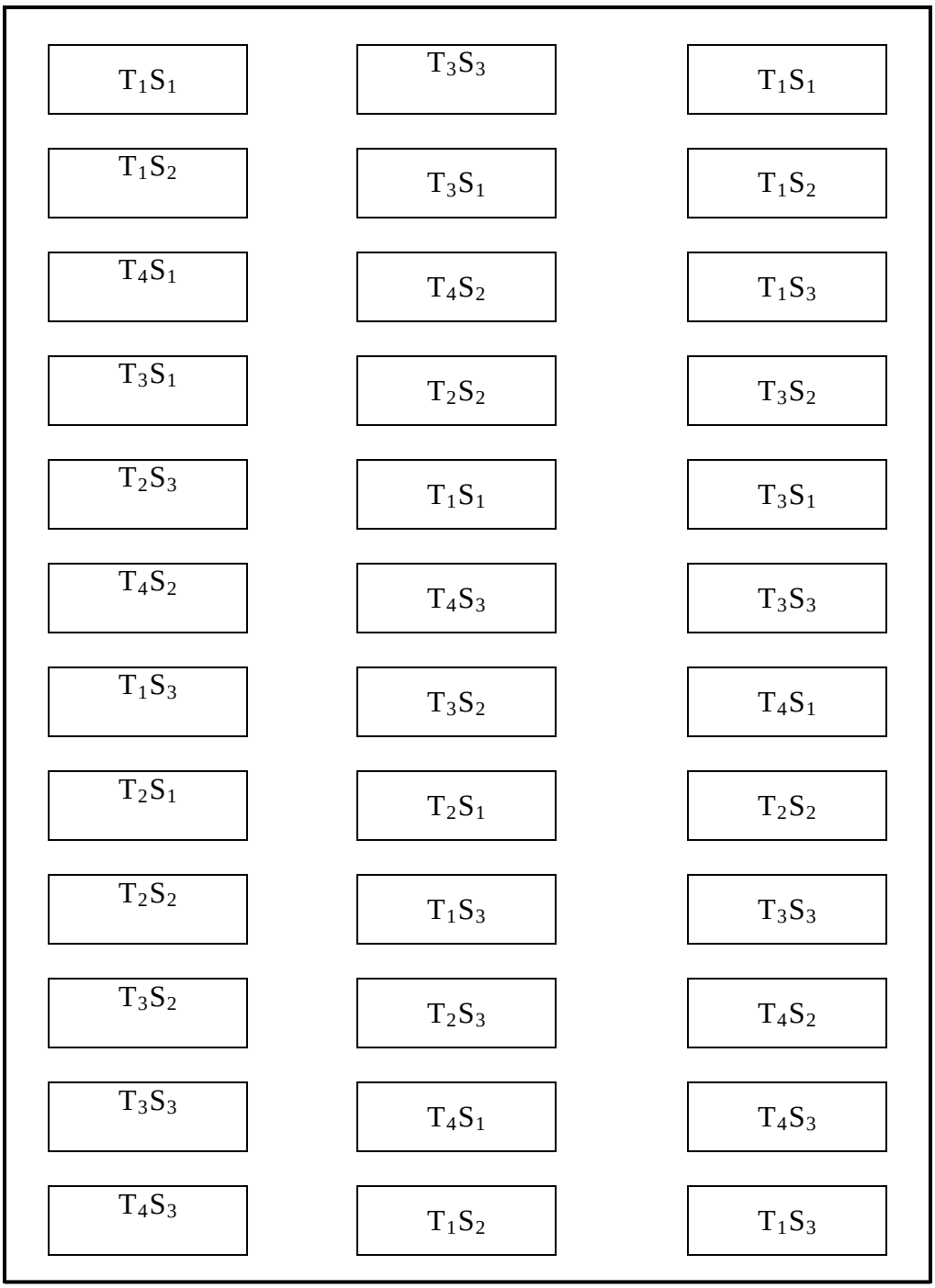
Table 1. Two factors consist of twelve (4×3=12) treatments combination. These were as follows:

Treatment Combination	Description	
	Spacing	Sowing time
$T_1 S_1$	20cm × 10cm	November 28, 2005
$T_1 S_2$	25cm × 15cm	November 28, 2005
$T_1 S_3$	30cm × 20cm	November 28, 2005
$T_2 S_1$	20cm × 10cm	December 08, 2005
$T_2 S_2$	25cm × 15cm	December 08, 2005
$T_2 S_3$	30cm × 20cm	December 08, 2005
$T_3 S_1$	20cm × 10cm	December 18, 2005
$T_3 S_2$	25cm × 15cm	December 18, 2005
$T_3 S_3$	30cm × 20cm	December 18, 2005
$T_4 S_1$	20cm × 10cm	December 28, 2005
$T_4 S_2$	25cm × 15cm	December 28, 2005
$T_4 S_3$	30cm × 20cm	December 28, 2005

T_1-1st sowing time (28 November)
T_2 - 2nd sowing time (8 December)
T_3- 3rd sowing time (18 December)
T_4- 4th sowing time (28 December)

S_1 - 1st spacing (20cm×10cm)
S_2 - 2nd spacing (25cm×15cm)
S_3 - 3rd spacing (30cm×20cm)

Figure 1. Lay out of the experiment



Total Plot: 36, Plot size: 1.5m x 2m

No. of Replication: 3

Plot to plot distance: 0.5m, Block to block distance: 1m

3.6. Design of the experiment

The two factors experiment was laid out in a RCB Design with three replications. The whole experimental area was 24.5m × 8.0m, which was divided into three blocks. Each block was again divided into 12 plots and hence there were 36 (12×3) unit plots. The treatments were assigned randomly in each block separately. The size of unit plot was 2.0m ×1.5m. The distance between two adjacent blocks and plots were 1.0 m and 0.5 m respectively.

3.7. Seed Soaking and Treatment

Carrot seeds were soaked into water for 12 hours and then wrapped with a piece of thin cloth prior to sowing. Then they were spread over polythene sheet for two hours to dry. The seeds were treated with Vitavex-200 @ 3g/100g seed.

3.8. Seed Rate and Seed Sowing

Seeds were used at the rate of 3 Kg/ha as narrated by Rashid (1993), consequently 59 g of seeds were used for the experimental area. Seven, six and five shallow furrows for spacing-20cm × 10cm, 25cm × 15cm and 30cm × 20cm at a distance of 20, 25 and 30 cm, with 1.5 cm depth were made in each plot respectively. Seeds were sown on different times and different spacing as per treatments. Before seed sowing, Savin 85 WP @ 2 kg/ha was applied to each plot for precautionary measures against ants and worms infestation to the seed and seedlings.

3.9. Land preparation

The selected land for the experiment was first opened on November 20, 2005 by disc plough and it was exposed to sun for seven days prior to next ploughing. The land was ploughed six times by tractor to obtain vigorous tilth. Deep ploughing and good tilth was necessary for getting better yield of the crop (Ahmad, 1969b). Laddering to break the soil clods and pieces was followed with each ploughing. All weeds and stubbles were removed and the land was finally prepared through addition of the basal doses of manure and fertilizers. Plots were prepared according to design and layout. Finally soil of each plot was treated by Seven 80 WP @ 2 kg/ha

to protect the young plant from the attack of mole cricket, cutworm and ants. Irrigation channels were made around each block.

3.10. Manure and Fertilizers

Urea, Triple Superphosphate (TSP) and Muriate of Potash (MP) were used as sources of nitrogen, phosphorus and potassium, respectively. Moreover, well-decomposed cow dung was applied to the field.

Manure and fertilizers were applied as per recommendation by Rashid (1983) and their methods of application were given below:

Manure and fertilizers	Amount		Quantity as basal dose	Quantity as top dressed
	Per hectare	Per plot		
Cow dung	12 ton	5.44 kg	Total	-
Urea	150 kg	45g	50%	50%
Triple Superphosphate	125 kg	37.5g	Total	-
Muriate of Potash	175 kg	52.5g	50%	50%

Source: Rashid (1983)

The total amount of cow dung and TSP, and 50% of total dose of Urea and Muriate of Potash (MP) were applied during land preparation. The rest amount of Urea and Muriate of potash (MP) were applied after 35 days of seed sowing.

3.11. Intercultural Operation

Emergence of seedlings started about six days after sowing. Different amount of plants per plot were found due to different spacing. Different plant spacing in different plot was adjusted by thinning at two stages like 15 and 30 days after sowing.

i. Thinning

Seedlings were thinned out two times. First thinning was done after 15 days of sowing keeping three seedlings in each site at requisite distance as per treatment. The second thinning was done after 30 days of sowing keeping only one seedling in each hole.

ii. Weeding

Weeding was done at two times. First weeding was done after 15 days of sowing when seedlings were thinned. Second weeding was done after 35 days of sowing before application of second dose fertilizer.

iii. Irrigation

The field was irrigated five times during the whole period of plant growth. Just after sowing light watering was done with fine watering can. Surface rust was broken after each irrigation. The second, third, fourth and fifth watering were done at 20, 35, 55 and 75 days after sowing of seeds respectively.

iv. Insects and diseases Management

Precautionary measures against Fusarium rot were taken by spraying Dithane M-45 @ 2 g /litre water. The crop was infested by cutworms (*Agrotis ypsilon)* during the early stage of growth of seedlings in the month of February. This insect was controlled initially by beating and hooking, afterwards by spraying Dieldrin 20 EC @ 0.1%.

v. Fertilizer top dressing

Recommended Urea, Muriate of Potash (MP) was top dressed after four weeks of sowing followed by light irrigation.

3.12. Collection of data

i) Number of leaves per plant

Number of leaves was counted 15 days interval after 40 days of sowing and continued to harvest. Ten plants in each plot were used to count number of leaves per plant.

ii) Foliage length per plant

Length of the largest leaves was considered as the foliage length. It was measured by using a meter scale and recorded in centimeter (cm). Ten plants in each plot were used to measure foliage length per plant.

iii) Fresh foliage weight per plant

Leaves of ten fresh plants in each plot were detached by sharp knife and fresh weight was taken by using a balance and recorded in gram (g).

iv) Foliage dry matter per plant

Leaves were detached from the root and kept in an oven at 70-80^{0}C for 72 hours. After drying, the leaves were kept in a desiccator containing blue silica gel. Fifteen minutes later the samples were weighed by using electric balance and recorded in gram (g).

v) Root length per plant

Ten plants were uprooted and detached from foliage parts. Then the length of modified roots was measured by scale and recorded in centimeter.

vi) Root diameter per plant

Ten selected plants were used to determine root diameter. Root diameter was measured at the time of harvesting from the middle portion with slide calipers and recorded in centimeter (cm).

vii) Root fresh weight per plant

Ten selected carrot roots were used to determine root fresh weight. Modified roots were detached by knife from the foliage part and fresh weight was taken by using balance and recorded in gram (g).

viii) Root dry matter per plant

Ten selected carrot root were used to determine root dry weight. Immediate after harvest roots were weighed initially, then chopped and kept it in an oven at 70-80^{0}C for 48 hours in order to get constant weight. (AOAC, 1965). The dry weight of root was measured by electric balance and was considered as dry weight and recorded in gram (g).

$$\text{Percentage of dry matter} = \textbf{Error! Bookmark not defined.}\frac{\text{Fresh weight of root (g)}}{\text{Dry weight of root (g)}} \times 100$$

ix) Cracking root per plot

The percentage of cracking roots was estimated by using the following formula-

$$\text{Percentage of cracking root} = \frac{\text{No.of cracked root}}{\text{Total no. of root}} \times 100$$

x) Branched root per plot

After harvest the branched roots were counted and the percentage was calculated by the following formula-

$$\%\text{ of branched root} = \frac{\text{Percentage of branched root}}{\text{Total no. of root}} \times 100$$

xi) Gross yield of roots per plot (kg)

Gross yield of roots per plot was calculated by using the following formula-

$$\text{Gross yield (kg/plot)} = \frac{\text{Area of single plot (mxm) x Average yield per plant (g) x 10000}}{\text{Spacing (cmxcm)x1000}}$$

xii) Gross yield of roots per hectare (t)

Gross yield of roots per hectare was calculated by using the following formula-

$$\text{Gross yield (t/ha)} = \frac{\text{Area (ha) x Average yield per plant (g) x 10000}}{\text{Spacing (cmxcm) x 1000 x 1000}}$$

xiii) Marketable yield per plot (kg)

Marketable yield was recorded excluding cracked and branched roots from each plot and expressed in kg.

Marketable yield = Gross yield − Non marketable yield (No. of cracked root and branched root)

vix) Marketable yield per hectare (t)

Marketable yield of roots per hectare was calculated by conversion of the marketable root weight per plot and recorded in ton.

3.13. Harvesting

The crop was harvested periodically for data collection. Randomly selected ten plants were harvested each time from each unit plot at 10 days interval. The harvesting was started after 105 days from each date of sowing. Final harvest was done when most of the roots of carrot showed the sign of maturity i.e. after 105 days of sowing.

3.14. Cost analysis

Cost and return analysis was done according to the procedure of Alam *et al*. (1989)

3.15. Statistical Analysis

The recorded data on different growth and yield parameters were calculated for statistical analysis. Analyses of variances (ANOVA) for most of the characters under consideration were performed with the help of MSTAT program. Treatment means were separated by Duncane's Multiple Range Test (DMRT) at 5% level of significance for interpretation of the results.

RESULTS AND DISCUSSION

The results of the present experiment were presented in Tables 2 to 11 and figures 2 to 11 on the effect of sowing time and spacing on the growth and yield of carrot.

The results of the analysis of variance of the data on different plant characters obtained from present investigation were presented in Appendices IV to XIII. The tabulated results have been discussed below under the following headings.

4.1 Plant height

Four different sowing times were statistically significant in respect of plant height of carrot (Figure 2). It varied from 53.31 cm to 26.82 cm. The maximum plant height (53.31 cm) was observed from the plants planted on 28 November (T_1) while the minimum (26.82 cm) on 28 December (T4). The result under the treatment T_1 predicted that early sowing performed longer plant height compared to late sowing (T_4) (Figure 2). There were optimum environmental conditions for carrot grown on late November among the other three sowing dates. All environment factors especially temperature supported for vegetative growth simultaneously. The results were in agreement with the findings of Tadgirwar *et al.* (2003). They obtained tallest plant height from early sowing.

The plant height was varied significantly due to the variation of spacing (Figure 3). It ranged from 48.09 cm to 31.76 cm. The tallest plant was observed from the spacing of 30cm x 20cm (S_3) while the shortest from the spacing of 20cm x 10cm (S_1). The plants under the treatment of S_3 (30cm x 20 cm) had enough space for vegetative growth and had less nutritions competition compared to other plants sown under the treatment S_1 (20cm x 10 cm) and S_2 (25cm x 15cm). The findings were not agreed with Muhammad - Amjad and Anjum -MA (2001) due to different environmental conditions between Bangladesh and Pakistan.

A significant interaction was found between sowing times and spacing on plant height (Table 9). The plant height varied from 20.12 cm to 61.65 cm. The tallest plant (61.65 cm) was observed

from the treatment of T_1S_3 followed by others. The shortest plant (20.12 cm) was recorded from the treatment of $T_4S_{1.}$

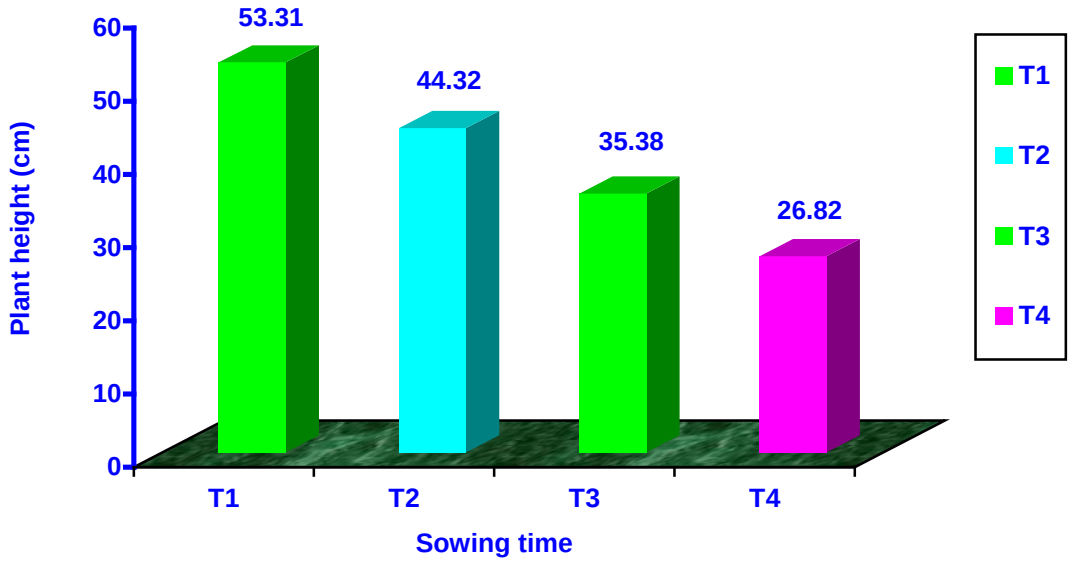


Figure 2. Effect of sowing times on plant height (cm) of carrot.

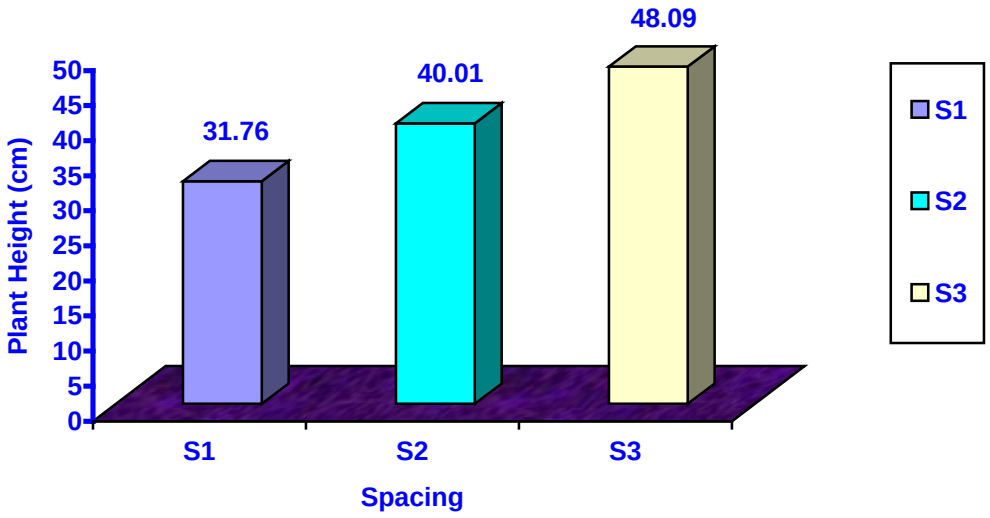


Figure 3. Effect of spacing on plant height (cm) of carrot.

4.2. Number of leaves per plant:

A significant variation was observed on leaves per plant in four sowing times (Table 2). It ranged from 8.40 to 15.38. The highest (15.38) number of leaf per plant was obtained from the plants grown at 28 November which was significantly differed from all other treatments except T_2 (8 December). The lowest number of leaves (8.40) per plant was obtained from plants grown on 28 December (T_4) which was statistically similar to the plants grown on 18 December (T_3). Results revealed that there was an increasing tendency in number of leaves per plant grown on 28 November (T_1) than 8 December (T_2) and decreasing up to 18 December (T_3) from 28 December (T_4). The present results agreed with the results obtained by Bussell and Dallenger (1972).

Leaves per plant were found significant due to different spacing. The leaf number of different spacing varied from 9.44 to 14.46 (Table 2). The maximum number of leaves (14.46) was found at 30 cm × 20 cm spacing (S_3) and the minimum (9.44) was found at 20 cm × 10 cm spacing (S_1) because plants at 30 cm ×20 cm spacing could uptake more nutrients than other plants due to higher spacing. After words in treatment 30 cm × 20 cm, the number of leaves increased but decreased in other treatment due to senescence. The variation of leaves number per plant as affected by time of sowing might be to the variation in the environmental conditions during growing period.

The interaction effect of sowing time and spacing showed significant variation on leaves per plant (Table 2). The number of leaves per plant varied from 6.41 to 18.39. The highest (18.39) number of leaves was recorded from the treatment T_1S_3 that was statistically similar to those of T_1S_2 and T_2S_3. The lowest (6.41) number of leaves was found from T_4S_1 that was statistically similar to those of T_3S_1 and T_4S_2.

Table 2. Effect of sowing time and spacing on leaves per plant of carrot

Spacing	Leaves per plant				Spacing mean
	T_1	T_2	T_3	T_4	
S_1	12.47bc	10.43cd	8.463de	6.410e	9.44b
S_2	15.27ab	13.33 bc	10.26cd	8.127de	11.75ab
S_3	18.39a	15.26ab	13.49bc	10.69cd	14.46a
Sowing dates mean	15.38a	13.01ab	10.74bc	8.408c	11.87

CV (%) = 17.45

Means Followed by uncommon letter under the same factor are significantly differed at 5% level by DMRT.

T_1 = 28 November
T_2 = 8 November
T_3 = 18 December
T_4 = 28 December

S_1 = 20cm × 10cm
S_2 = 25cm × 15cm
S_3 = 30cm × 20cm

4.3. Weight of fresh leaves

Weight of fresh leaves under study varied significantly due to four different sowing times (Table 3). The weight of fresh leaves varied from 54.17g to 120.5g. The maximum leaf fresh weight (120.5g) was obtained from the plants when grown on 28 November (T_1), which was statistically dissimilar to the plants grown on 8 December (T_2). The minimum fresh weight of leaves (54.17g) was observed when grown on 28 December (T_4). Results revealed that the weight of fresh leaf gradually decreased from T_1 to T_4. The present results were supported by Bussell and Dallenger (1972).

Significant variation was found in respect of weight of fresh leaves by different spacing**.** The weight of fresh leaf varied from 115.7g to 64.03g (Table 3). The maximum weight (115.7g)was found to the plants were grown at the spacing of 30cm × 20cm (S_3) while the minimum (64.03g) in 20cm ×10cm (S_1). The weight of fresh leaf was gradually decreased from the plants grown from spacing S_1 (20cm×10cm) to S_3 (30cm×20cm)

The interaction effect of sowing time and spacing was statistically significant in respect of weight of fresh leaf (Table 3). The weight of fresh leaf ranged from 40.58g to 150.7g. The maximum fresh weight was recorded from the plants grown at the spacing of 30cm × 20cm and planted at 28 November (T_1S_3) while the minimum (40.58g) at the spacing of 20cm×10cm and grown on 28 December (T_4S_1) which was statistically similar to that of T_4S_2 and T_3S_1. The highest weight of fresh leaf was statistically different from the other treatment combinations

Table 3. Effects of sowing time and spacing on weight of fresh leaves (g) of carrot

Spacing	Weight of fresh leaves (g)				Spacing mean
	T_1	T_2	T_3	T_4	
S_1	90.38de	72.21ef	52.96fg	40.58g	64.03c
S_2	120.4b	100.3cd	80.62de	50.98g	88.07b
S_3	150.7a	130.5b	110.7bc	70.96ef	115.7a
Sowing dates mean	120.5a	101.0b	81.43c	54.17d	89.27

CV (%) = 12.65

Means Followed by uncommon letter under the same factor are significantly differed at 5% level by DMRT

T_1 = 28 November
T_2 = 8 November
T_3 = 18 December
T_4 = 28 December

S_1 = 20cm × 10cm
S_2 = 25cm × 15cm
S_3 = 30cm × 20cm

4.4. Weight of dry leaves:

Leaves dry weight was statistically significant due to four sowing times. It varied from 23.29g to 44.34g. The highest weight (44.34 g) of dry leaves was observed in the treatment T_1 (28 November) which was statistically similar to the treatment T_2 (8 December) and the lowest (23.29 g) was found from T_4 (28 December) (Table 4).

The significant result was found in respect of dry weight of leaves of carrot. It varied from 30.46g to 37.75g. The S_3 (30cm×20cm) treatment gave the maximum weight (37.75g) of dry leaves and the minimum (30.46 g) was found in treatment S_1 (20cm×10cm) that was statistically similar to the treatment S_2 (25cm×15cm) (Table 4).

The combined effect of sowing time and spacing was statistically significant in respect of leaves dry weight. It varied from 20.21g to 48.97g. The maximum leaves dry weight (48.97g) was found in the treatment T_3S_1 which was statistically similar to that of T_2S_1 and T_2S_2 and the minimum (20.21g) was in the treatment T_4S_1 which is statistically significant to that of T_3S_3 and T_4S_3 (Table 4)

Table 4. Effects of sowing time and spacing on weight of dry leaves of carrot

Spacing	Weight of dry leaves (g)				Spacing mean
	T_1	T_2	T_3	T_4	
S_1	39.54bc	34.16cd	27.91de	20.21f	30.46b
S_2	44.51ab	39.43bc	30.39de	23.49ef	34.46ab
S_3	48.97a	41.76ab	34.03cd	26.16ef	37.73a
Sowing dates mean	44.34a	38.45a	30.78b	23.29c	34.22

CV (%) = 12.27

Means Followed by uncommon letter under the same factor are significantly differed at 5% level by DMRT.

T_1 = 28 November
T_2 = 8 November
T_3 = 18 December
T_4 = 28 December

S_1 = 20cm × 10cm
S_2 = 25cm × 15cm
S_3 = 30cm × 20cm

4.5. Root length

The root length of carrot was significantly influenced by four sowing times (Table 5). The longest root (13.01cm) was observed from the plants grown on 28 November (T_1) which was significantly similar to the plants grown on 8 December (T_2) but significantly differed from other sowing dates. The shortest root (6.69 cm) was found from the plants grown on 28 December (T_4). This was also significantly differed from other sowing dates. A statistical similar result was also found from the treatment T_4 (28 December) and T_3 (18 December). This result showed that the root length progressively increased with the planting of late November (T_1) and early December (T_2) but decreased with the planting of mid-December (T_3) to late-December (T_4). The present results agreed with Rashid and Shakur (1986).

There was a significant difference among the different spacings of carrot production in respect of root length (Table 5). The largest root (11.02 cm) was recorded from the plants grown at the spacing of 30cm ×20cm (S_3) which was significantly similar to the plants grown at the spacing of 25cm ×15cm (S_2) and the smallest root was recorded from the plants grown at the spacing of 20cm ×10cm (S_1), which was statistically significant compared to others.

A significant interaction was found between sowing time and spacing on root length of carrot (Table 5). The root length ranged from 6.14cm to 14.82cm. The longest root (14.82cm) was recorded from the treatment T_1S_3. The shortest root (6.14cm) was found from the treatment T_4S_1 that was statistically similar to that of T_4S_2 and T_4S_3. The plants grown at the spacing of 30cm ×20cm (S_3) uptook more nutrients and rate of photosynthesis was higher than other plants so that vegetative growth was increased and the roots were rich in carbohydrate. They got more space to develop than other plants. So the root length was increased.

Table 5. Effects of sowing time and spacing on length of root (cm) of carrot

Spacing	Length of root (cm)				Spacing mean
	T_1	T_2	T_3	T_4	
S_1	11.13cd	10.09de	6.974fg	6.143g	8.583b
S_2	13.09b	11.66bc	8.310ef	6.923fg	9.994ab
S_3	14.82a	12.33bc	9.930de	7.010fg	11.02a
Sowing dates mean	13.01a	11.36a	8.405b	6.692b	9.86

CV (%) = 10.38

Means Followed by uncommon letter under the same factor are significantly differed at 5% level by DMRT.

T_1 = 28 November
T_2 = 8 November
T_3 = 18 December
T_4 = 28 December

S_1 = 20cm × 10cm
S_2 = 25cm × 15cm
S_3 = 30cm × 20cm

4.6. Diameter of root

Root diameter exhibited significant variation among the four sowing times (Table 6). The root diameter was progressively decreased with the advance of sowing date. The highest root diameter (17.03 cm) was obtained from the plants grown on 28 November (T_1), which was statistically similar to the plants grown on 8 December (T_2). The lowest root diameter (10.82cm) was obtained from the plants grown on 28 December (T_4), which was statistically similar to the plants grown on 18 December (T_3). The findings of the present study in root diameter agreed with Bose *et al.* (1986).

Significant difference was observed among the different spacing of carrot production in respect of root diameter (Table 6). The maximum root diameter (15.97 cm) was found from the plants sown at the spacing of 30cm × 20cm (S_3) which was statistically similar to that of the spacing of 25cm × 15cm (S_2) while the minimum root diameter (10.65 cm) at the spacing of 20cm ×10cm (S_1). The plants under the treatment S_3 (30cm × 20cm) had to have sufficient space to develop their root in soil so that the root diameter was increased enough than others. The findings agreed with Mecollum *et al.* (1986).

The interaction effect of sowing time and spacing statistically influenced the root diameter of carrot (Table 6). The root diameter varied from 8.4 cm to 20.39 cm. The highest root diameter (20.39) was observed from the treatment combination of T_1S_3 where plants were grown at the spacing of 30cm×20cm and grown on 28 November (T_1). The plants under the treatment T_1S_3 were statistically similar to that of T_2S_3.

Table 6. Effects of sowing time and spacing on diameter of root (cm) of carrot.

Spacing	Diameter of root (cm)				Spacing mean
	T_1	T_2	T_3	T_4	
S_1	13.30bc	11.49de	9.327ef	8.463f	10.65b
S_2	17.40ab	14.79bc	13.48bc	11.62de	14.32a
S_3	20.39a	16.67ab	14.45bc	12.38cd	15.97a
Sowing dates mean	17.03a	14.31ab	12.42b	10.82b	13.65

CV (%) = 17.51

Means Followed by uncommon letter under the same factor are significantly differed at 5% level by DMRT.

T_1 = 28 November
T_2 = 8 November
T_3 = 18 December
T_4 = 28 December

S_1 = 20cm × 10cm
S_2 = 25cm × 15cm
S_3 = 30cm × 20cm

4.7. Weight of fresh roots

Weight of fresh roots was significantly differed by four sowing times (Table 7). The highest fresh root weight (172.5 g) was observed from the plants grown on 28 November (T_1), which was significantly similar to the plants planted on 8 November (T_2). The lowest fresh root weight (82.81 g) was observed from the plants grown on 28 December (T_4). The results were in agreement with the findings of Rashid and Shakur (1986). They reported that carrot is a photo and thermo sensitive crop. Growth of root was developed under a sustainable environmental condition. Later sowing could not provide their suitable environmental conditions to grow up properly. So earlier sowing was the best for higher fresh weight of root.

Different spacing for carrot production was found to have significant effect on fresh root weight (Table 7). It ranged from 115.7g to 160.4g. The maximum fresh root weight (160.4g) was obtained from the plants grown at the spacing of 30cm×20cm (S_3), which was significantly differed from others. The minimum fresh root weight (115.7g) was obtained from the plants grown at the spacing of 20cm×10cm (S_1). The plants, which were grown under the spacing 30cm×20cm (S_3), had more space to develop their roots and had lesser nutrient competition. Whatever the plants grown under the spacing of 25cm×15cm (S_2) and 20cm×10 (S_1) cm had comparatively less space and they had a nutrient competition among the plants.

The interaction effect of sowing time and spacing was statistically significant in respect of weight of fresh root (Table 7). The weight of fresh root ranged from 217.4g to 64.94g. The maximum fresh weight (217.4g) was recorded from the plants grown at the spacing of 30cm × 20cm and planted on 28 November i.e. combined treatment T_1S_3 while the minimum (64.94g) at the spacing of 20cm×10cm and planted on 28 December i.e. combined treatment T_4S_1 which was statistically similar with T_4S_2 . The highest weight of fresh root was statistically differed from other treatment combinations

Table 7. Effects of sowing time and spacing on weight of fresh root (g) of carrot

Spacing	Weight of fresh root (g)				Spacing mean
	T_1	T_2	T_3	T_4	
S_1	136.5de	133.3de	128.1e	64.94g	115.7 c
S_2	163.7bc	158.4bc	140.2cd	88.51fg	137.7 b
S_3	217.4a	178.0b	151.4cd	94.97f	160.4 a
Sowing dates mean	172.5 a	156.5ab	139.9b	82.81c	137.88

CV (%) = 10.29

Means Followed by uncommon letter under the same factor are significantly differed at 5% level by DMRT.

T_1 = 28 November
T_2 = 8 November
T_3 = 18 December
T_4 = 28 December

S_1 = 20cm × 10cm
S_2 = 25cm × 15cm
S_3 = 30cm × 20cm

4.8. Weight of dry root per plant

Significant variation of root dry weight among four sowing times was recorded which varied from 25.51g to 10.10g (Table 8). The maximum root dry weight was observed to the plants grown on 28 November (T_1) and the minimum on 28 December. It found that root dry weight was gradually decreased from 1st sowing date (T_1) to 4th sowing date (T_4). The roots were produced under optimum environmental condition like temperature, light and humidity on 28 November in compare to others. It was probably the reduction of photosynthesis and possible backflow of carbohydrate and unable to synthesize carbohydrate. Further, Reduction of root dry weight was resulted from non-accumulation of food due to aging of plants and less of stored reserved due to respiration (Hoque and Bhuyan, 1983).

The effect of different spacing significantly influenced in respect of root dry weight (Table 8) which varied from 21.80g to 13.78g. The maximum root dry weight was found at the spacing of 30cm x 20cm (S_3) which was similar to the spacing of 25cm x 15 cm (S_2) and the minimum was found at the spacing of 20cm x 10cm (S_1). It resulted that wider spacing (S_3) gave more consumption of dry mater of root than less densely grown of carrot. The result was agreed by Muhammad Amjad and Anjum-M.A. (2001).

The combined effect of four sowing times and different spacing significantly influenced the root dry weight (Table 8). The root dry weight varied from 32.47g to 8.43g. The maximum root dry weight (32.47g) was obtained on 28 November (T_1) at the spacing of 30 cm x 20 cm (S_3) i.e. The combined treatment of T_1S_3 gave the highest result and the minimum root dry weight (8.43g) was observed on 28 December (T_4) at the spacing of 20 cm x 10 cm (S_1) i.e. combined treatment of T_4S_1 gave the lowest result. The highest root dry weight represented by T_1S_3 was statistically similar with T_3S_1. The lowest root dry weight represented by T_4S_1 was statistically similar with T_4S_2 and T_4S_1.

Table 8. Effects of sowing time and spacing on weight of dry root (g) of carrot

Spacing	Weight of dry root (g)				Spacing mean
	T_1	T_2	T_3	T_4	
S_1	18.61cd	15.64 de	32.47 a	8.427g	13.78b
S_2	25.44 b	18.61 cd	15.64de	11.32 fg	18.92a
S_3	32.47 a	25.44b	17.36 cd	10.57 fg	21.80a
Sowing dates mean	25.51a	20.99b	16.06c	10.10d	18.17

CV (%) = 11.12

Means Followed by uncommon letter under the same factor are significantly differed at 5% level by DMRT.

T_1 = 28 November
T_2 = 8 November
T_3 = 18 December
T_4 = 28 December

S_1 = 20cm × 10cm
S_2 = 25cm × 15cm
S_3 = 30cm × 20cm

4.9. Percentage of cracking root:

The percentage of cracking root was varied significantly among the four sowing times (Figure 4). The maximum cracking percentage (14.50%) was obtained from T_4 treatment i.e. delay sowing gave a huge amount of cracking roots. But the early sowing i.e. T_1 treatment gave minimum percentage of cracking root which was 3.27%. This might be caused by early sowing helps in development and vigorous growth of carrot root.

The mean value of cracking percentage with the treatment of three spacing varied significantly (Figure 5). The maximum percentage (11.73%) of cracking root was observed in the treatment of S_3 (30cm×20cm) while the minimum (6.55%) in S_1 (20cm×10cm)

The combined effect of different sowing times and spacing was highly significant among the treatment mean (Table 9). The maximum cracking percentage of root (18.33%) was observed from the treatment of T_3S_3 which was statistically similar with T_4S_2. The minimum (2.06%) cracking percentage of root was observed from the treatment of T_1S_1 which was statistically similar with T_1S_2 and T_1S_3. The result showed that the early and dense sowing influenced positively on growth of plant. All the process of consumption of nutrient, air, water and light to become a competitive situation under less spacing comparatively than wider spacing.

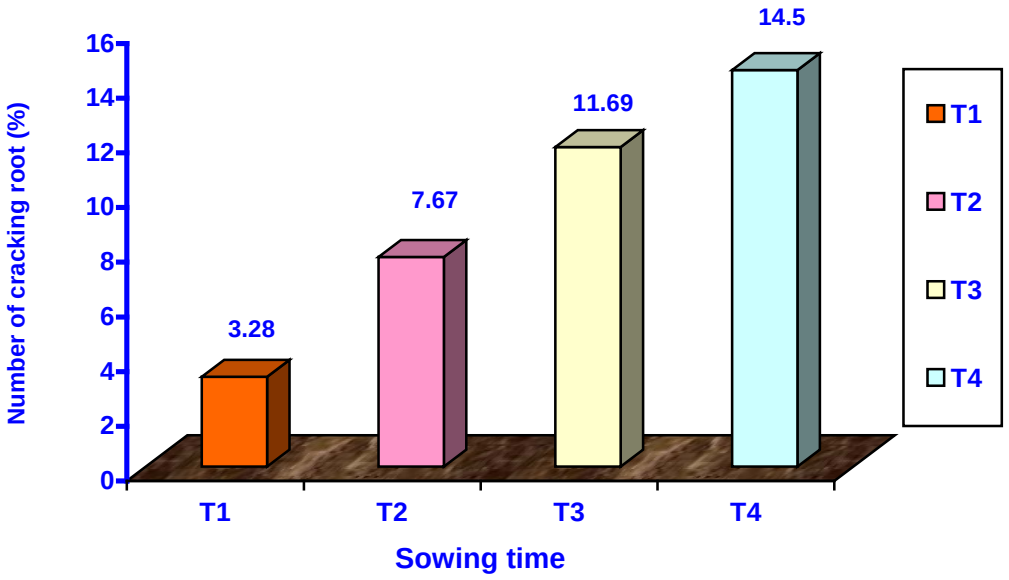


Figure 4. Effect of sowing times on the number of cracking root percentage of carrot.

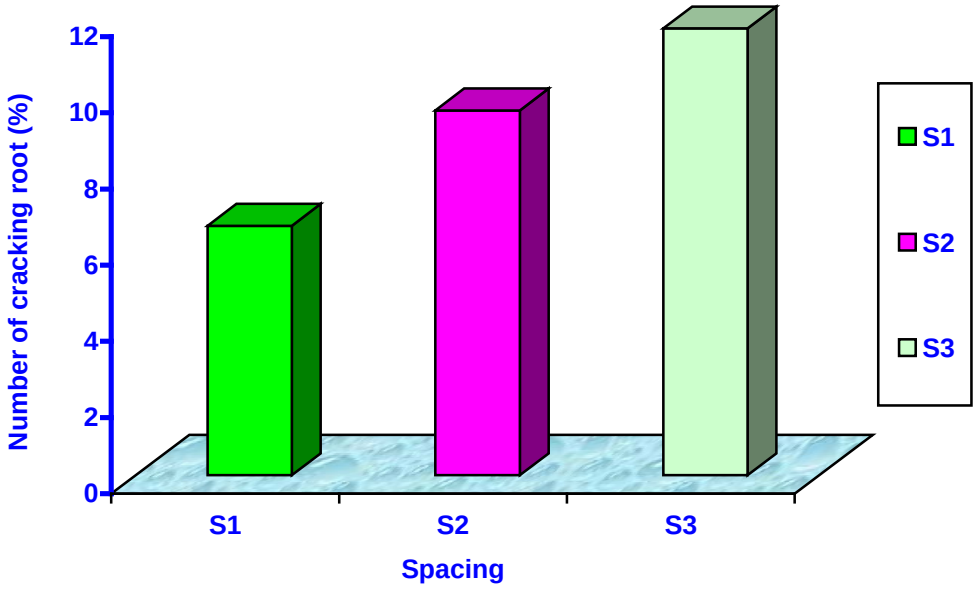


Figure 5. Effect of spacing on the number of cracking root percentage of carrot.

4.10. Percentage of branched root:

The percentage of branched root was varied significantly among the four sowing times (Figure 6). It ranged from 5.73% to 22.31%. The maximum percentage (22.31%) of branched root was found on 28 December (T_4) which was statistically similar to that of 18 December (T_3). The minimum percentage (5.73%) of branched root was found on 28 November (T_1) i.e. delay sowing gave a huge amount of branched root. But the early sowing i.e. treatment T_1 gave minimum percentage of breached root. This might be caused by adverse environmental conditions like temperature, humidity, light and rainfall

The mean value of branched percentage with the treatment of three spacing varied significantly (Figure 7). It ranged from 12.15% to 20.44%. The maximum percentage (22.44%) of branched root was observed to the plants planted at the spacing of 20cm x 10cm (S_1) and the minimum percentage (12.15%) of branched root was obtained at the spacing of 30cm x 20cm (S_3) which similar to the spacing of 25cm x 15cm (S_2). The result showed that the smallest spacing (S_1) gave maximum branched root percentage and minimum branched percentage was found from the highest spacing (S_3) (Figure 6).

The combined effect of different sowing times and spacing was highly significant in respect of branched root (Table 9). The maximum percentage (30.00%) was observed from the treatment of T_4S_1 and the minimum percentage (5.00%) was observed from the treatment of T_1S_3 which was statistically similar to that of T_1S_2 and T_2S_3. The result showed that the early sowing in association of dense planting effected on plant growth and development as well as the development of root.

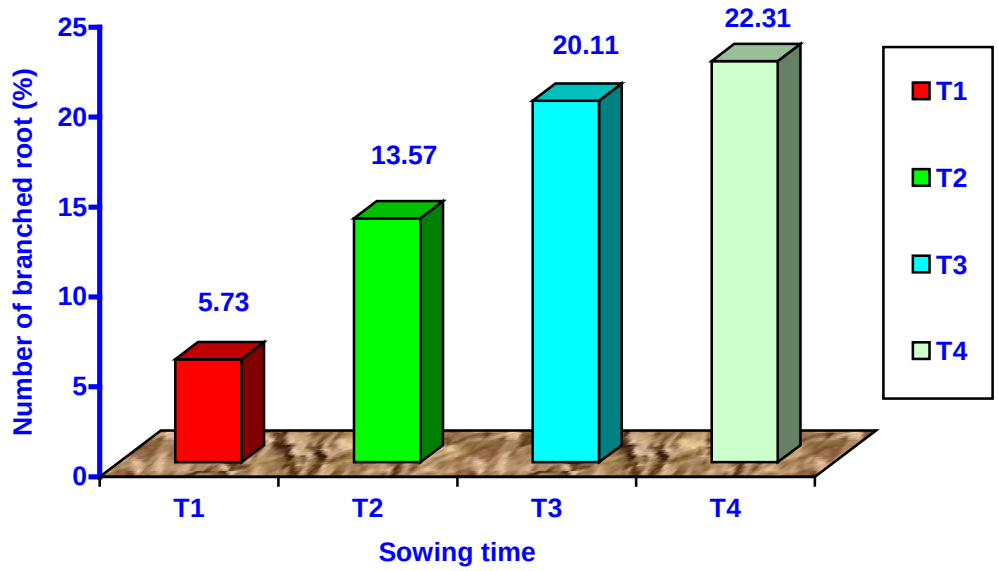


Figure 6. Effect of sowing times on number of branched root percentage of carrot.

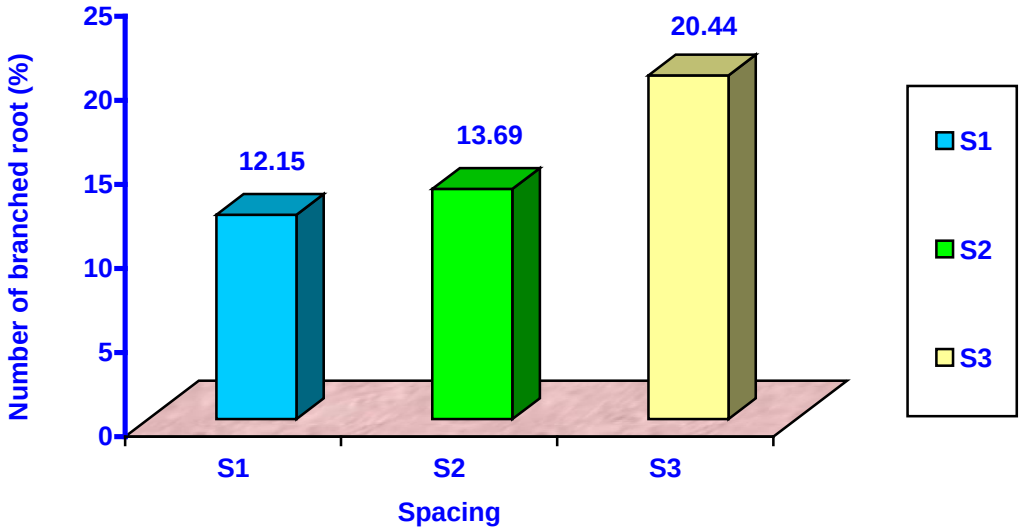


Figure 7. Effect of spacing on the number of branched root percentage of carrot.

4.11. Gross yield of root per plot and hectare

Gross yield of carrot per plot was statistically significant in respect of different sowing times (Figure 8). The maximum yield (28.65 ton/ha or 8.38 kg/plot) was found from the treatment T_1 (28 November) which was statistically similar to the treatment T_2 (8 December). The minimum yield (3.23 kg/plot or 10.48 ton/ha) was found from the treatment of T_4 (28 December). The result showed that early sowing gave the highest yield than other three sowing times. The yield of root was gradually decreased from T_1 (28 November) to T_4 (28 Decembr). The result was agreed with Pariari and Maity (1992).

Significant variation was found in respect of yield by different spacing (Figure 9). It ranged from 27.02 ton/ha to 12.70 ton/ha. (8.46 kg/plot to 3.7 kg/plot). The maximum yield (27.02 ton/ha or 8.46 kg/plot) was found from the treatment of S_1 (20cm x 10cm) while the minimum in S_3 (30cm x 20cm). The highest yield was found under the spacing of S_1 (20cm x 10cm) due to be set up more number of plants than other two spacing in the same size of plot. The result was agreed with Bussell (1975). He obtained the highest yield from the highest densities used in the experiments.

In association of different sowing times and spacing in respect of gross yield of root was not varied significantly (Table 9). However, the maximum (38.17 ton/ha or 11.17 kg/plot) and the minimum yield (6.67 ton/ha or 2 kg/plot) were obtained from the treatment combination of T_1S_1 and T_4S_3 respectively. Where as the maximum and minimum results were observed statistically similar with the combined treatment of T_2S_1 and T_4S_2 respectively. Similarly, treatment combination of T_1S_3 and T_3S_2 performed statistically same yield of carrot root that was 18.03 ton/ha and 17.7 ton/ha respectively.

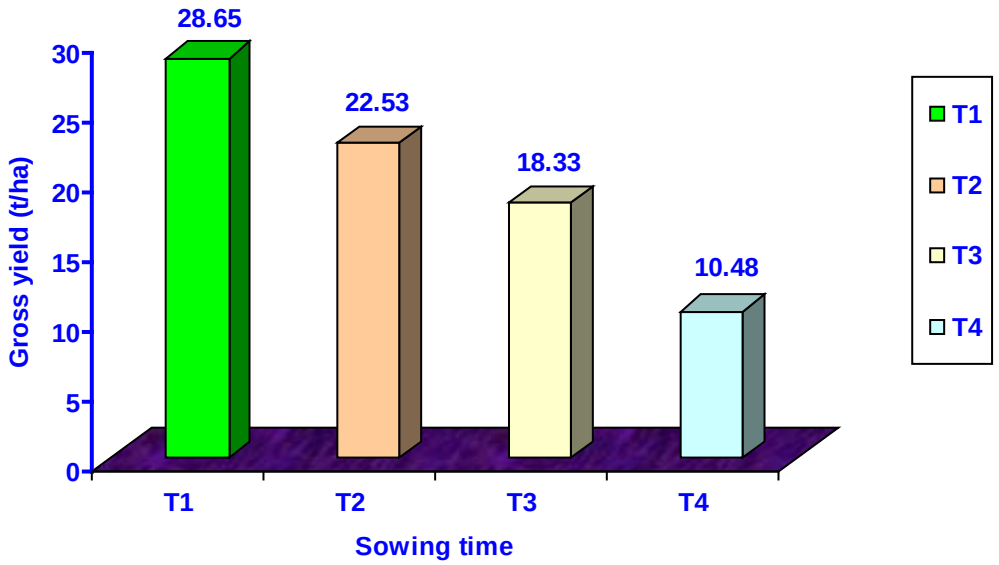


Figure 8. Effect of sowing time on gross yield (t/ha) of carrot.

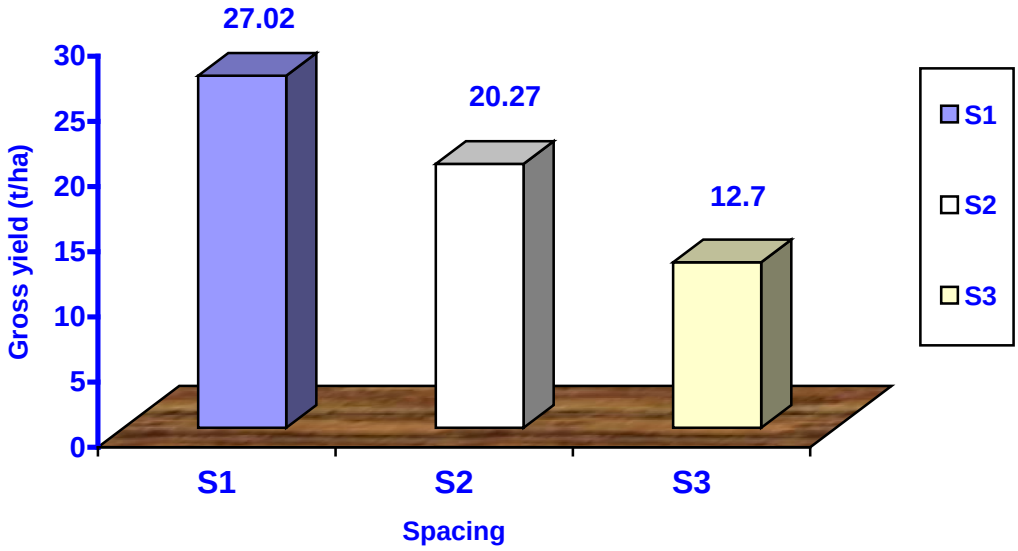


Figure 9. Effect of spacing on gross yield (t/ha) of carrot.

4.12. Marketable yield per plot and hectare

Marketable yield was calculated by subtracting non-marketable yield from gross yield of carrot. Marketable yield also varied significantly due to different sowing times (Figure 10). It ranged from 24.66 t/ha to 6.34 t/ha (7.35kg/plot to 2.12kg/plot). The highest marketable yield (24.66 t/ha or 7.35 kg/plot) was found from the treatment of T_1 (28 November). The second highest marketable yield (5.64 kg/plot or 16.13 t/ha) was found from the treatment of T_2 (8 December) and the lowest marketable yield (2.12 kg/plot or 6.345 t/ha) was obtained from the treatment of T_4 (28 December). The result showed that early sowing on 28 November performed the highest marketable yield and it was gradually decreased from the treatment of T_1 (28 November) to T_4 (28 December), Frampton-C (1996) (Figure 10).

Significant variation was observed among the different spacing of carrot production in respect of marketable yield (Figure 11). It ranged from 23.18 t/ha to 8.33 t/ha (6.92 kg/plot to 2.50 kg/plot). The maximum (23.18 t/ha or 6.92 kg/plot) marketable yield was obtained from the treatment of S_1 (20cm x 10cm) while the minimum (8.33 t/ha or 2.50 kg/plot) in S_3 (30cm x 20cm). The highest marketable yield was observed under the treatment S_1 due to the highest amount of seedlings to be set up than other two treatments. This result was agreed with Frohlich *et al.* (1971). He reported that increasing plant density enhanced the marketable yield.

The combined effect of different sowing times and spacing was significantly differed in respect of marketable yield (Table 9). The marketable yield ranged from 34.33 t/ha to 3.13 t/ha (10.32 kg/plot to 2.77 kg/plot). The highest marketable yield (34.33 t/ha or 10.32 kg/ha) was obtained from the treatment of T_1S_1 while the lowest (3.135 t/ha or 2.77 kg/ha) in T_4S_3. The lowest marketable yield under the treatment of T_4S_3 was statistically similar with T_1S_3.

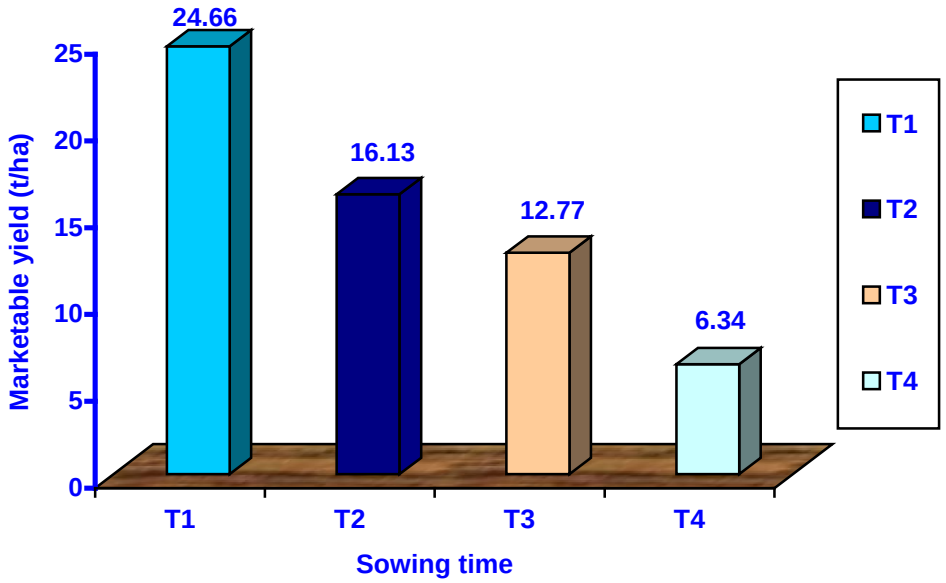


Figure 10. Effect of sowing times on marketable yield (t/hat) of carrot.

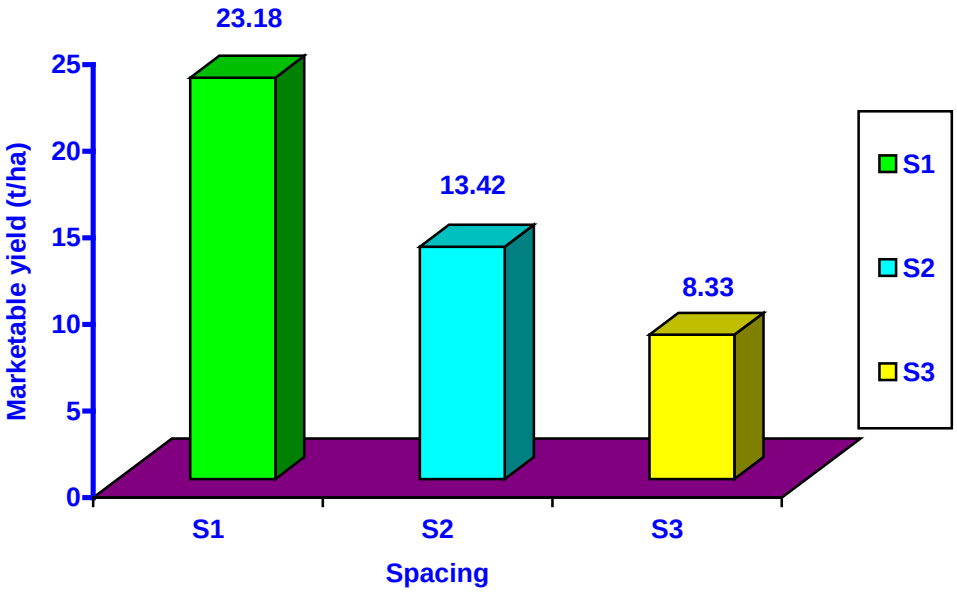


Figure 11. Effect of spacing on marketable yield (t/hat) of carrot.

Table 9. Interaction effect of plant height (cm), gross yield (kg/plot), gross yield (t/ha), marketable yield (kg/plot), marketable yield (t/ha), % of cracking root and % of branched root of carrot.

Treatment Combination	Plant height (cm)	Gross yield (t/ha)	Gross yield (kg/plot)	Marketable yield (t/ha)	Marketable yield (kg/ha)	% of cracking root	% of branched root
T_1S_1	44.51bc	38.17a	11.17a	34.33a	10.32a	2.067 f	5.00 g
T_1S_2	53.75ab	29.43b	8.557bc	24.14bc	7.220c	3.82 ef	6.42fg
T_1S_3	61.6a	18.36cd	5.410d	15.50de	4.510ef	3.94 ef	5.77 fg
T_2S_1	35.23de	28.63b	10.00ab	28.63b	8.633b	5.00 e	9.30 ef
T_2S_2	44.86bc	38.17a	7.213c	10.41ef	5.530de	7.54 d	11.41 e
T_2S_3	52.87ab	29.43b	4.567de	9.343fg	2.770gh	10.47 c	20.00 c
T_3S_1	27.19ef	18.36cd	8.233bc	20.48cd	6.000d	6.42 de	15.00 d
T_3S_2	35.22de	28.63b	5.310d	12.49ef	3.727fg	10.33 c	15.32 d
T_3S_3	43.72cd	10.17ef	3.033ef	5.353gh	5.530de	18.33 a	30.00 a
T_4S_1	20.12f	14.65de	4.457de	9.267fg	2.770gh	12.71 bc	19.31 c
T_4S_2	26.20ef	10.15ef	3.233ef	6.633fg	6.000d	16.62 a	21.62 c
T_4S_3	34.13e	6.65f	2.000f	3.135h	3.727fg	14.17 b	26.00 b
CV%	12.65	17.34%	16.65%	21.18%	15.24%	15.36	13.05

T_1 = 28 November
T_2 = 8 November
T_3 = 18 December
T_4 = 28 December

S_1 = 20cm × 10cm
S_2 = 25cm × 15cm
S_3 = 30cm × 20cm

4.13. Cost and return analysis:

Material, non-material and overhead costs were recorded for all the treatment for unit plots and calculated per hectare basis (marketable yield). The price of carrot roots at the local market was also noted. The cost and return analysis were done and presented at table .11 and appendices V.

The total cost of production ranged between TK 52266 to TK 47709 among the treatments combination. The cost of variation was found for different amount of seed to be required in several treatments combination due to different spacings. The highest cost of production (TK 52266) was involved in the treatment combinations of T_1S_1, T_2S_1, T_3S_1 and T_4S_1 while the lowest cost of production (TK 47709) was involved in the treatment combinations of T_1S_3, T_2S_3, T_3S_3 and T_4S_3. Number of plants was highest in the treatment S_1 (20cm×10cm) in the same area than other treatments like S_2 and S_3. So cost of production was higher than others. On the other hand number of plants was lower in the treatment of S_3 (30cm×20cm) in the same area than others. So cost of production was lower in spacing S_3 (30cm×20cm) than others. The gross return from different treatments combination ranged between TK 206400 to TK 24600 per hectare. Gross return was the total income through sale proceeds of marketable yield of carrot root @ TK 6000/t.

The benefit cost Ratio (BCR) was found to be the highest (2.95) in the treatment combination of T_1S_1 and the lowest BCR (-0.03) was recorded with T_4S_2. In the treatment combination of T_1S_1, marketable yield was higher than others and cost of production was more or less to other treatments combination. It was found that combination treatments from T_1S_1 to T_3S_2 were profitable for carrot production but combined treatments from T_3S_3 to T_4T_3 were non-profitable when production cost is higher than gross yield. Results revealed that marketable yield might be better in the treatment combination of T_1S_2 to be considered net-return respectively.

Table 10 (A): Material cost (TK)

Treatment combination	Carrot seed (3 kg/ha)	Manures and Fertilizers				Pesticide	Subtotal. l (A)
		Cow dung (12 t/ha)	Urea (150 kg/ha)	TSP (125 kg/ha)	MP (175 kg/ha)		
T_1S_1	6000	4800	1050	2000	1575	2000	17425
T_1S_2	3340	4800	1050	2000	1575	2000	14765
T_1S_3	2140	4800	1050	2000	1575	2000	13565
T_2S_1	6000	4800	1050	2000	1575	2000	17425
T_2S_2	3340	4800	1050	2000	1575	2000	14765
T_2S_3	2140	4800	1050	2000	1575	2000	13565
T_3S_1	6000	4000	1050	2000	1575	2000	17425
T_3S_2	3340	8000	1050	2000	1575	2000	14765
T_3S_3	2140	4800	1050	2000	1575	2000	13565
T_4S_1	6000	4800	1050	2000	1575	2000	17425
T_4S_2	3340	4800	1050	2000	1575	2000	14765
T_4S_3	2140	4800	1050	2000	1575	2000	13565

Carrot seed @ TK 2000/Kg
Cow dung @ TK 0.40/Kg
Urea @ TK 7.00/Kg
TSP@ TK 16.00
MP @ TK 9.00

T_1-1st sowing date
T_2 - 2nd sowing
T_3- 3rd sowing date
T_4 -4th sowing date

S_1 - 1st spacing (20cm×10cm)
S_2 - 2nd spacing (25cm×15cm)
S_3 - 3rd spacing (30cm×20cm)

Table 10 (B): Non- Material cost (TK/ha)

Treatment combination	Land Preparation	Manures & fertilizers application	Seed sowing	Intercultural operation	Harvesting	Sub total II (B)	Total input cost (A+B)
T_1S_1	7000	1050	2660	2100	7700	20510	37935
T_1S_2	7000	1050	2660	2100	7700	20510	35275
T_1S_3	7000	1050	2660	2100	7700	20510	34075
T_2S_1	7000	1050	2660	2100	7700	20510	37935
T_2S_2	7000	1050	2660	2100	7700	20510	35275
T_2S_3	7000	1050	2660	2100	7700	20510	34075
T_3S_1	7000	1050	2660	2100	7700	20510	37935
T_3S_2	7000	1050	2660	2100	7700	20510	35275
T_3S_3	7000	1050	2660	2100	7700	20510	34075
T_4S_1	7000	1050	2660	2100	7700	20510	37935
T_4S_2	7000	1050	2660	2100	7700	20510	35275
T_4S_3	7000	1050	2660	2100	7700	20510	34075

Labour cost @ Tk. 70 per day

T_1-1st sowing date (28 November)

T_2 - 2nd sowing (8 December)

T_3- 3rd sowing date (18 December)

T_4- 4th sowing date (28 December)

S_1 - 1st spacing (20cm×10cm)

S_2 - 2nd spacing (25cm×15cm)

S_3 - 3rd spacing (30cm×20cm)

Table 10 (c): Overhead cost and total cost of production (TK)

Treatment combination	Overhead cost (TK)			Sub total (Overhead cost)	Total cost of production (Total input cost + Overhead cost)
	Cost from leased land	Interest of rooming capital (13% of total input cost/year)	Miscellaneous cost (5% of total input cost)		
T_1S_1	7500	4932	1899	14331	52266
T_1S_2	7500	4586	1764	13850	49125
T_1S_3	7500	4430	1704	13634	47709
T_2S_1	7500	4932	1899	14331	52266
T_2S_2	7500	4586	1764	13850	49125
T_2S_3	7500	4430	1704	13634	47709
T_3S_1	7500	4932	1899	14331	52266
T_3S_2	7500	4586	1764	13850	49125
T_3S_3	7500	4430	1704	13634	47709
T_4S_1	7500	4932	1899	14331	52266
T_4S_2	7500	4586	1764	13850	49125
T_4S_3	7500	4430	1704	13634	47709

Table 11. Cost and return of carrot due to sowing time and spacing:

Treatment combination	Marketable yield of carrot (t/ha)	Gross return (TK/ha)	Total cost of production (TK/ha)	Net return (TK/ha)	BCR
T_1S_1	34.40	206400	52266	154134	2.95
T_1S_2	24.06	144360	49125	95235	1.94
T_1S_3	15.03	90180	47709	42471	0.89
T_2S_1	28.76	172560	52266	120294	2.30
T_2S_2	18.43	110580	49125	61455	1.25
T_2S_3	9.23	56380	47709	8671	0.18
T_3S_1	20.0	120000	52266	67734	1.29
T_3S_2	12.03	72180	49125	23055	0.47
T_3S_3	5.06	30360	47709	-17349	-0.04
T_4S_1	9.13	54780	52266	2514	0.05
T_4S_2	5.71	34280	49125	-14845	-0.03
T_4S_3	4.1	24600	47709	-23109	-0.05

Price of carrot @TK.6000/t

Gross Return = Market yield × Price of carrot (Tk/ha) Carrot

Benefit cost Ratio (BCR) = Gross return ÷ Total cost of production

T_1: 1st sowing date (28 November)
T_2: 2nd sowing date (8 December)
T_3: 3rd sowing date (18 December)
T_4: 4th sowing date (28 December)

$S_{1:}$ 1st spacing (20cm ×10cm)
$S_{2:}$ 2nd spacing (25cm ×15cm)
$S_{3:}$ 3rd spacing (30cm ×20cm)

SUMMARY AND CONCLUSION:

An experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka to evaluate the effects of sowing times and spacings on the growth and yield of carrot during November 2005 to April 2006. The experiment comprised of two different factors such as (i) four sowing times Viz. T_1 (28 November), T_2 (8 December), T_3 (18 December), T_4 (28 December) and (ii) three spacings viz. S_1 (20cm×10cm), S_2 (25cm×15cm) and S_3 (30cm×20cm) respectively.

Number of leaves per plant ranged from 9.45 to 14.46 among the three spacings. The maximum (14.46) number of leaves per plant was found at the spacing of S_3 (30cm×20cm). Number of leaves per plant also varied due to different sowing times. The maximum (15.38) number of leaves per plant was found in carrot which was sown on 28 November 2005 (T_1) and the minimum on 28 December 2005 (T_4) i.e. the maximum number of leaves per plant was found in the combined treatment of T_1S_3.

The plant height was varied among the combined treatments mean of different sowing times and spacing. In respect of sowing time, the largest leaf (53.31 cm) was found in treatment of T_1 and the shortest was in T_4. On the other hand considering the spacing, the tallest leaf was recorded in the treatment of S_3 and the shortest (26.82 cm) was in treatment of S_1 i.e. the maximum plant height was recorded from the combined treatment of T_1S_3.

Fresh weight of leaf varied from 54.17 g to 120.5 g among the different sowing times. The maximum (150.7g) fresh weight of leaf was recorded on 28 November (T_1) at the spacing of 30cm × 20cm. The combined treatment of T_1S_3 was performed the highest fresh weight of root.

The dry weight of leaf varied from 20.21 g to 48.97g among the sowing times and spacing. The maximum (48.97g) dry weight of leaf was found in treatment of T_1S_3. Leaf dry weight also varied due to different spacings. The maximum (44.34g) dry weight of leaf was observed in the treatment of T_1 and the minimum (23.29) was in T_4. But incase of spacing the maximum (37.73g) dry weight of leaf was obtained in S_3 and minimum (30.46) was in S_1 treatment.

The length of root was differed among the different sowing times. The longest (13.01cm) root was found in the treatment of T_1 and the shortest (6.69cm) was in T_4. The tallest (11.02cm) root was noticed in S_3 and the shortest (8.58cm) at S_1. But in the combined treatment of T_1S_3 was produced tallest (14.82cm) root while T_4S_1 was produced the shortest (6.14cm) root.

The fresh weight root varied significantly among the sowing times and different spacing. The maximum (217.4g) fresh weight of root was obtained from the combined treatment of T_1S_3 while the minimum (64.94g) in T_4S_1. The treatment of T_1 and T_4 were performed the maximum and minimum fresh weight of root while the spacing was S_3 and S_1.

The weight of dry root showed significant variation among the four sowing times at different spacings. The maximum (32.47g) weight of dry root was found on 28 November (T_1) at the spacing of 30cm×20cm (S_3) i.e. the combined treatment of T_1S_3 while the minimum (8.43g) on 28 December (T_4) at the spacing of 20cm×10cm (S_1)i.e. the combined treatment of T_1S_3. Dry weight of root gradually decreased from 1^{st} to 4^{th} sowing date.

Root diameter differed significantly among the sowing times at different spacing. The maximum (20.39 cm) root diameter was obtained from the combined treatment

of T_1S_3 while the minimum (8.46cm) was in T_1S_3. Early sowing and wider spacing performed the highest root diameter.

There was significant variation was recorded among the different sowing times and spacing in respect of cracking percentage and branched percentage of carrot root. The highest cracking (18.33%) and branched (30.00%) percentage was obtained in late sowing (T_3) under wider spacing (S_3). The highest (18.33%) cracking percentage was observed in the combined treatment of T_3S_3 while the lowest (2.06%) in T_1S_1. Similarly, the height (30.00%) branched percentage was found in T_4S_1 while the lowest (5.00%) in T_1S_3.

Gross yield and marketable yield were also significantly influenced by different sowing times and spacings. The highest gross yield (38.17t/ha) was observed in treatment combination of T_1S_1 while the minimum (6.65 ha) in T_4S_3. The highest marketable yield (34.33 t/ha) was noticed under the combined treatment of T_1S_1 and the lowest (3.13 t/ha) in T_4S_3.

The maximum gross yield (38.17 t/ha) was found in T_1S_1 and the minimum (6.65 t/ha) was in T_4S_3. The maximum (34.33 t/ha) and the minimum (3.135 t/ha) marketable yield were also found in the treatment of T_1S_1 and T_4S_3. The highest (2.95) Benefit Cost Ratio (BCR) was observed in T_1S_1 and the lowest (-0.03) was in T_4S_2. The yield and yield contributing characters were increased with the closest spacing but growth parameters were increased with the widest spacing. Gross yield and marketable yield were increased in early sowing and decreased in delay sowing. In twelve treatments of combination of four sowing dates and three spacing, the maximum yield and marketable yield were in T_1S_1.

REFERENCES

Alim, A. 1974. An Introduction to Bangladesh Agriculture. First Edition, *M. Alim, Dhaka. p. 9.*

Anonymous, 1960. Soil Survey Report of Sadar Sub-Division in the District of Mynensingh. *Bull. No. 6. Agric. Chem. Section. Deptt. of Agric. Govt. of East Pakistan.*

Banga, O.1976. In Evolution of Crop plants by N.W. *Simmands (Ed.) London, London.*

Barnes, N.C.1936. Effect of some environmental factors on growth and colour of carrots.*Bulletin Cornell Univ. Agric. Expt. Sta.,186p.*

Berry-NA; Wratten-SD and Frampton-C.1997. Effects of sowing and harvest dates oncarrot rust fly (Psila rosae) damage to carrots in Canterbury. *New-Zealand-Journal-of-Crop-and-Horticultural-Science. 1997, 25: 2, 109-115; 12*

Bose, T. K. and M. G. Som. 1986. Vegetable crops in India. First Edn. *Naya Prakassh, Calcutta, India. P. 2-9, 409-425.*

Bussell, W. T. and J. Dallenger. 1972. Baby carrot : a report on main crop varieties trials,. *New Zealand Commercial Grower, 27 (9): 29-31*.

Bussell, W. T. 1978. Studies on baby carrot production. *New Zealand Experimental Agriculture, 6 (2): 131-137.*

Chauhan, V.V.S. 1989. Cole crops, Vegetable Production in India. *Agra, India. pp. 117- 147.*

Dragland, S. 1986. Plant density and row spacing in carrots. *Forskning of. Forsik i Landbruket, 37 (3): 139-145.*

FAO. 2000. FAO production year Book, *Food and Agriculture Organization, Rom, Italy, 45: 146.*

Farazi, M. A. 1983. Effects on plant spacing and different levels of nitrogen and potash on the yield of carrot. *An M. S. thesis, Department of Horticulture, BAU, Mymensingh. 41p.*

Freman, R.E. and P.K. Simon. 1983. *J. Amer. Soc. Hort. Sci. 108 (1):50-56.*

Fritz, D. and J. Habben, 1977. Influence of harvesting date on the quality of different carrot cultivars. *Gartenbauwissenschaft, 42(4): 185-190.*

Golder, P. C. 2000. Studies on growth, yield and quality of banana as affected by growth regulators. *Ph. D. Thesis, Dept. of Hort., BSMRU, Gazipur, p.23.*

Goodman, O. 1953. Further investigation of some of the factors affecting quality and yield in carrot crops. *J. Dep. Agric. Dublin. 50: 104-128.*

Gupta, U. C. and E. W. Chipman. 1976. *Plant and Soil, 44: 559-566.*

Ilic-Z.1997.Influence of sowing time and growing space on the possibility of producing carrot seeds through the "seed-seed" system. *Poljoprivredni Fakultet, Pristina, Yugoslavia. Selekcija-i-Semenarstvo. 1997, 4: 3-4, 133-137; 8*

Jaiswal,-M-D; Adpawar,-R-M; Parlawar,-N-D and Yadgirwar,-B-M. 2003. Effect of planting dates and spacing on growth, seed yield and quality of carrot. *Department of Horticulture, Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola - 444 104 (M.S.)India. Annals-of-Plant-Physiology. 2003; 17(2): 117-119*

Lipari, V. 1975. Yield, growth pattern and morphological characteristics of carrot root in the autumn-winter spring cycle in relation to planting density and maturing. *Rivista di Agronomia, 9 (2/3): 240-245.*

Lucchesi, A. A., k. Minami, A. N. Kalil, J. N. Kiryu and J. JR. Perri, 1976. The productivity of radish in relation to spacing. *Anais da Escola Superior de Agriculturae ``Luizde Queiroz'', 33: 5777-582.*

Mason, R. R. and T. C. Tong. 1971. The production of carrots in Hongkong. *Agricultural Science Hongkong, 1 (5/6): 272-278.*

Mack, H.J. 1979. Effect of fertilizers, row spacing and harvest dates on table carrots. *J. Amer. Soc. Hort. Sci. 104(5):717-720.*

McCollum, T. G., S. J. Locascio and J. M. White. 1986. Plant density and row arrangement effects on carrot yields. *J. Amer. Soc. Hort. Sci., 111(5): 648-651.*

Mitchell-JP; Allaire-Leung-SE; Sanden-BL and Wu-L. 2000. Sprinkler spacing does not affect carrot yield and quality. *Department of Vegetable Crops, University of California, Davis, CA 95616, USA. HortTechnology. 2000, 10: 2, 370-373; 13 ref.*

Muhammad-Amjad and Anjum-MA.2001. effect of root size, plant spacing and umbel order on the quality of carrot seed. *Department of Horticulture, University of Agriculture,Faisalabad-38040,Pakistan.International-Journal-of-Agriculture-and- Biology. 2001, 3: 2, 239-242; 11*

Nilsson, T. 1987. Growth and chemical composition of carrots as influenced by the time of sowing and harvest. *J. Agric. Sci., 108(2): 459-464.*

Nogueira, ICC, F das C, Nogueira and MZ de, Negreiros. 1982. Effect of plant spacing on yield of carrot (*Daucus carota L.*) cv. *Kuroda Nocional. Proc. Trop. Reg., Amer. Soc. Hort. Sci., 25: 125-127.*

Pariari-A and Maity-TK 1992. Growth and yield of carrot (Daucus carota L.) cultivars as influenced by sowing dates. *Department of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur 741 252, West Bengal, India. Crop-Research-Hisar. 1992, 5:Supplement, 158-162; 5 ref.*

Pariari-A and Maity-TK.1992.Growth and yield of carrot (Daucus carota L.) cultivars asinfluenced by sowing dates. *Department of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur 741 252, West Bengal, India. Crop-Research-Hisar. 1992, 5: Supplement, 158-162; 5*

Pashine-YP; Deshmukh-PP; Diware-DV; Deshmukh-SV and Uke-PC. 1993. Effect of sowing time on the yield of carrot (*Daucus carota* L.*). Punjabrao Krishi Vidyapeeth, Akola-444104 (M.S.), India. Annals-of-Plant-Physiology. 1993, 7: 1, 34-135; 2*

Shantha-Nagarajan; Pandita-VK; Deepti-Sharma; Nagarajan-S and Sharma-D. 1999. Effect of sowing time and umbel order on emergence characteristics of Asiatic carrot *Daucus carota* L. *Indian Agricultural Research Institute, Regional Station, Karnal 132 001, India. Seed-Research. 1998, publ. 1999, 26: 2, 125-130; 11 ref.*

Pavlek, P. 1977. Effect of plant density on carrot yield. *Plojprivredna Znanstvena Smotra, 42: 67-73.*

Peirce, L.C. 1987. Vegetable: Characteristics, production and marketing. *John Wiley and Sons. Inc. New York. pp. 251-252.*

Rashid, M. M. 1983. ``Shabjir Chash'' (in Bangla). Published by Begum Shahla Rashid. *BARI Residential Area, Joydebpur, Gazipur, Dhaka. p. 173.*

Rashid, M. M. and M.A. Shakur, 1986. Effect of date of planting and duration of growing period on the yield of carrot. *Bangladesh Horticulture, 14(2): 28-32.*

Rashid, M. M. 1993. Shabji Bijnan (Olericulture) (in Bangla). *Published by Bangla Academy, Dhaka, Bangladesh. p. 502-507.*

Salam, A. 1995. Effect of plant spacing and time of harvesting on yield of carrot. *An M. S. thesis. Dept. of Hort. BAU, Mymensingh. pp. 52-72.*

Salter, p. J., L. E. Currah and J. R. Fellows. 1979. The effect of plant density, spatial arrangement and time of harvesting on yield and root size in carrots. *J. Agric. Sci., 93(2): 431-440.*

Shanmugavelu, K. G. 1989. Production technology of vegetable crops. *Oxford & IBH publishing Co., Pvt. Ltd.,New Delhi, Calcutta. pp. 397-399.*

Thompson, H. C. and W. C. Kelly. 1957. Vegetable crops. *5th Edn., TATA McGraw-Hill Publishing Company Ltd., New Delhi. pp. 327-335.*

Taivalmaa-SL and Talvitie-H. 1997. The effects of ridging, row-spacing and seeding rate on carrot yield. *Agricultural Research Centre of Finland, Institute of Horticulture, Hyrkolantie 122, FIN-32810 Peipohja, Finland. Agricultural-and- Food-Science-in-Finland. 1997, 6: 5-6, 363-369; 18 ref.*

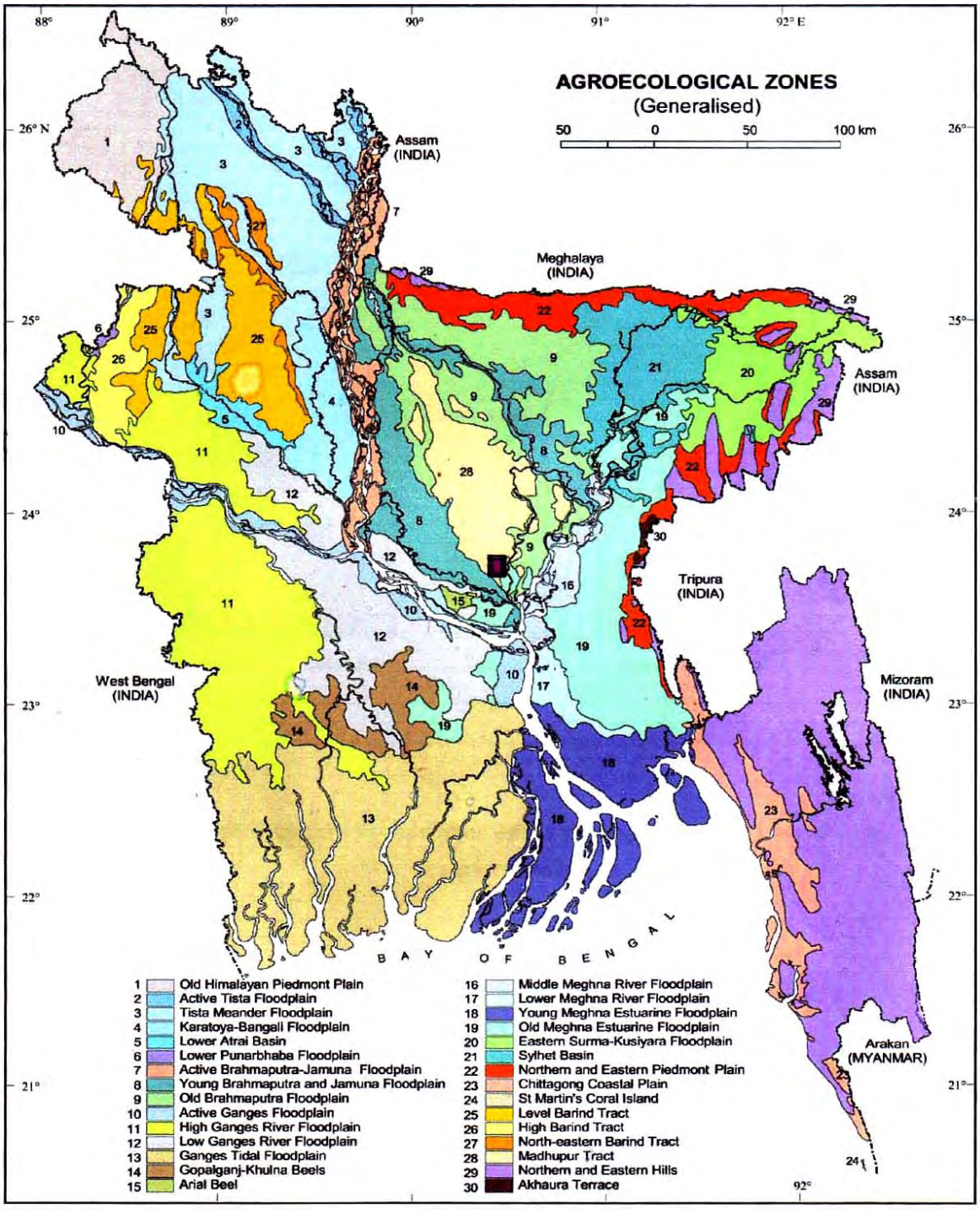
Watt, R.L. and Merril. 1964. Composition of Foods, Row, Processed, Prepared. *Agriculture Hand Book No. 8, U.S.A. Dept. Agriculture, Washington.*

Woolfe, J. A. 1989. Nutrition Aspects of Sweet potato Roots and Leaves. *Improvement of sweet potato (Ipomea batatas) in Asia; CIP. 1989. pp. 167-182.*

Yawalker, K.S. 1985. Vegetable crops in India. *Third edition. Mrs. K.K. Yawalker, Agri- Horticultural Publishing House, 52, Bajaj Nagar-440010,pp.210-220.*

APPENDICES

Appendix I. Map showing the experimental site under study



The experimental site under study

Appendix II. Soil analysis data of the experimental plot.

Chemical analysis

Properties	Content
Organic Carbon	0.75%
Total Nitrogen	0.09%
Phosphorus	41.89%
Exchangeable K	0.18 e mol (+) kg soil
P^H value	5.3

Mechanical analysis

Constituents	Percent
Sand	23
Silt	47
Clay	30
Textural class	Silty clay

Source: Soil Research Development Institute, Dhaka

Appendix III. Monthly records of temperature (^{0}C), rainfall (mm), relative humidity (%), soil temperature (^{0}C) and sunshine (lux) of the experimental site during the period from November 2005 to April 2006

Year	Month	*Air temperature (^{0}C)			Relative Humidity (%)	Rainfall (mm)	Soil temperature at different depth (^{0}C)			** Sunshine (hours)
		Max.	Min.	Mean			5cm	10cm	20cm	
2004	October	30.97	23.31	75.14	75.14	208	16.90	17.20	17.30	208.90
	November	29.45	18.63	24.04	69.52	00	13.8	14.40	14.80	233.20
	December	26.85	16.23	21.15	70.60	00	12.60	13.60	14.00	210.50
2005	January	24.52	13.86	19.19	68.46	04	11.30	12.40	13.00	194.10
	February	28.88	17.94	23.43	61.04	03	12.90	13.70	13.80	221.50
	March	32.22	21.78	27.00	66.69	155	16.20	17.10	17.20	210.20

*Monthly Average

**Monthly Total

Source: Bangladesh Meteorological Department (Climate Division), Agargaon, Dhaka-1207.

Appendix IV. Mean sum of square values of analysis of variance of the data on different growth and yield contributing characters of carrot

Sources of variation	Degrees of freedom	Mean square		
		Number of leaf	Weight of fresh leaf (g)	Dry weight of leaf (g)
Replication	2	52.738*	1246.60*	4.200*
Factor - A	3	80.625*	7208.947*	755.278*
Factor - B	2	75.570*	8027.615*	159.270*
Interaction- A×B				
Error	5	0.609*	156.610^{NS}	2.663*
	22	4.297	125.605	17.636
CV%		17.45	12.56	12.27
LSD 0.05		3.51	18.98	7.11

* = Significant at 5% level; ** = Significant at 1% level;
NS = Non Significant

Appendix V. Mean sum of square values of analysis of variance of the data on different growth and yield contributing characters of carrot

Sources of variation	Degrees of freedom	Mean square		
		Plant height (cm)	Weight of dry root (g)	Weight of fresh root (g)
Replication	2	494.81*	51.05*	58.84*
Factor - A	3	1172.51*	393.91*	13759.72*
Factor - B	2	800.03*	197.86*	5996.59*
Interaction- A×B				
Error	5	2.61*	25.61*	580.28 ^{ns}
	22	25.54	4.08	201.35
CV%		12.65	11.12	10.29
LSD 0.05		8.55	3.42	24.03

* = Significant at 5% level; ** = Significant at 1% level;

NS = Non Significant

Appendix VI. Mean sum of square values of analysis of variance of the data on different growth and yield contributing characters of carrot

Sources of variation	Degrees of freedom	Mean square			
		Gross yield of root (kg/plot)	Gross yield of root (ton/ha)	Marketable yield (kg/plot)	Marketable yield (ton/ha)
Replication	2	0.97*	59.478*	0.29*	48.822 ^{NS}
Factor - A	3	45.3*	523.928*	46.42*	523.213*
Factor - B	2	66.6*	616.073*	58.48*	682.878*
Interaction-A×B	5	1.79 ^{NS}	19.923^{NS}	3.2*	45.453 *
Error	22	1.031	12.019	0.52	10.057
CV%		16.65	17.34	15.24	21.18
LSD 0.005		1.71	5.870	1.21	5.370

* = Significant at 5% level; ** = Significant at 1% level;

NS = Non Significant

Appendix VII. Mean sum of square values of analysis of variance of the data on different growth and yield contributing characters of carrot

Sources of variation	Degrees of freedom	Mean square	
		Length of root (cm)	Diameter of root (cm)
Replication	2	1.613 ns	0.471*
Factor - A	3	72.986*	64.212*
Factor - B	2	17.992*	89.184*
Interaction - A×B			
Error	5	1.157 ^{NS}	1.512*
	21	1.050	5.712
CV%		10.38	17.51
LSD 0.05		1.73	4.04

*= Significant at 5% level
NS= Non Significant

Appendix VIII. Mean sum of square values of analysis of variance of the data on different growth and yield contributing characters of carrot

Sources of variation	Degrees of freedom	Mean square	
		Weight of fresh root (g)	Weight of dry root (g)
Replication	2	1.613	0.0824
Factor - A	3	72.986*	64.212*
Factor - B	2	17.992*	89.184*
Interaction - A×B			
Error	5	1.157*	1.512*
	21	1.050	5.712
CV%		10.38	17.51
LSD 0.05		24.03	3.421

*= Significant at 5% level
NS= Non Significant

Appendix IX. Nutritive content of carrot per 100 g edible portion according to Watt and Merrill (1964).

Constituents	Content/100 g	Constituents	Content/100 g
Water	88.6 g	Nicotinic acid	0.5 mg
Protein	1.1 g	Biotin	0.003 mg
Fat	9.1 g	Folic acid	0.008 mg
Total carbohydrate	9.1 g	K	31.1 mg
Fiber	1.0 g	Ca	39.0 mg
Vitamin A	1200 IU	Mg	21.0 MG
Vitamin B_1	0.06 mg	Fe	0.8 mg
Vitamin B_2	0.06 mg	P	37.0 mg
Vitamin B_{12}	60.12 mg	S	21.0 mg
Vitamin C	2-10 mg	Cl	40.0 mg
Vitamin E	0.45 mg	-	

Appendix X. Chemical composition of carrot per 100 g edible portions by Nilsson, T. (1987).

Constituents	Content/100 g
Water	82.2 g
Energy	45 calories
Protein	1.2 g
Calcium (Ca)	42 mg
Vitamin A	12000 IU
Vitamin C	4 mg
Thiamin	0.042 mg
Riboflavin	0.043 mg
Niacin	0.21 mg