STUDIES ON IRRIGATION, FERTILITY AND SPACING LEVELS ON CARROT SEED CROP (*Daucus carota* L.)

By

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Thesis submitted to the Chaudhary Charan Singh Haryana Agricultural University, Hisar in the partial fulfillment of the requirements for the degree of

Doctor of Philosophy in Vegetable Science

DEPARTMENT OF VEGETABLE SCIENCE
COLLEGE OF AGRICULTURE
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2006


Dedicated
To
My Parents

CERTIFICATE - I

This is to certify that this dissertation entitled **"Studies on Irrigation, fertility and spacing levels on carrot seed crop" (*Daucus carota* L.)"** submitted for degree of **Doctor of Philosophy**, in the subject of **Vegetable Science** of the Chaudhary Charan Singh Haryana Agricultural University, Hisar, is a bonafied research work carried out by **Vikash Hooda Admn. No. 2003A44D** under my guidance and supervision and that no part of this dissertation has been submitted for any other degree.

The assistance and help received during the course of investigation has been fully acknowledged.

A. C. Yadav 21.11.06

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CERTIFICATE - II

This is to certify that this dissertation entitled "**Studies on Irrigation, fertility and spacing levels on carrot seed crop" (*Daucus carota* L.)**" submitted by **Vikash Hooda, Admn. No. 2003A44D** to the Chaudhary Charan Singh Haryana Agricultural University, Hisar, in partial fulfilment of the requirements for the degree of **Doctor of Philosophy**, in the subject of **Vegetable Science**, has been approved by the Student's Advisory Committee after an oral examination on the same, in collaboration with an External Examiner.

MAJOR ADVISOR **EXTERNAL EXAMINER**

2.5.07

HEAD OF THE DEPARTMENT

9/5/07

DEAN, POST-GRADUATE STUDIES

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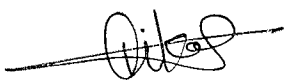

(Vikash Hooda)

CONTENTS

LIST OF TABLES

CHAPTER - I

Introduction

Carrot (*Daucus carota* L.) is a popular cool season root vegetable of Umbelliferae family. It is cultivated in temperate countries during spring and summer season while in tropical region during winter season. It is used in several forms namely salad, cooked vegetable, pickles and preserve etc. It is an ideal material for processing and preparing several products like pickles, sweet-meats, carrot powder and kanji. It has high nutritive value due to its high carotene content, the precursor of vitamin A. Fresh edible carrot contains 88.6 per cent water, 1.1 per cent protein, 0.2 per cent fat, 9.1 per cent carbohydrates, 1.0 per cent fiber, vitamin A 12000 I.U., vitamin B_1, B_2, C and minerals in traces (Chatfield, 1954).

The carrot varieties are divided into two groups viz., the European type, which are biennial and Asiatic type being annual. The Asiatic types produce seed in the plains while the seed of European type is produced in hilly areas in India. The demand for seed of subtropical varieties is solely met out from our subcontinent because these varieties are not grown in the temperate countries.

The vegetable crops being more remunerative, the area under carrot crop is increasing every year and the demand for quality seed is also increasing fast. The seed is the basic, most important and cheapest input and has profound influence on the ultimate yield of the crop. In carrot, the demand for quality seed especially of Asiatic type is not only within the country but there are possibilities of export to other countries in tropical and sub-tropical regions where seed production has not yet been commercially exploited.

The area under carrot in India is fairly large and is grown in 22,538 hectare with the production of 4.14 lakh tones (Thamburaj and Singh, 2003). However, the average seed yield and quality of seed is rather low, as little attention has been paid towards development of appropriate technology for seed production in carrot. In advanced countries like U.S.A. and Japan, seed production is highly specialized business and is carried out on most scientific manner.

In India, some information on the cultural practices such as root age, planting time etc. is available but information on optimum irrigation, plant spacing and fertility levels is limited.

A number of factors are responsible for quality seed production of carrot. Among these factors the optimum irrigation, fertility and plant spacing are the principle

factors, which affect both qualitative and quantitative yielding capacity of carrot seed crop. In the absence of precise information on these aspects of carrot seed production, enumerated above, the present study was therefore undertaken with the following objectives:

1. To study the effect of varying irrigation regimes, fertility and spacing levels on yield and quality of carrot seed crop.
2. To work out the optimum levels of irrigation, fertility and spacing and economics for the seed production of carrot.

CHAPTER - II

Review of Literature

2.1 Effect of irrigation

Plant growth and survival is associated with the water availability. Any degree of water imbalance will produce a proportionately deleterious derivative in physiological activity, growth and development. Scientific irrigation scheduling is a technique for determining the proper time and quantity of irrigation water. The major objective of irrigation scheduling is to avoid water deficit in crop plants and to obtain optimum yield under a particular agroclimatic conditions. An optimum irrigation schedule for a crop is generally decided from its water use pattern and susceptibility to water deficit at different stages of growth. Climatological approach, soil water regime and plant indices including the critical growth stages concept are commonly used criteria for scheduling of irrigation.

Macgillivray and Clemente (1949) reported that irrigation increased the yield of carrot seed. They also found that irrigation had little effect on seed germination and size.

In carrot medium and low soil moisture favoured high seed yield (Howthorn, 1952).

Baur and Wiebe (1968) carried out studies at Hannover on the effect of soil water content (100%, 75%, 50% of field capacity) on the emergence of carrot seed. They found that emergence fell with increase in soil water content.

Marouelli *et al.* (1990) observed highest seed yield of carrot by applying irrigation when soil moisture tension reached 75 KPa. They further reported that germination of 1000 seed weight was not significantly influenced by the treatments, El-Beheidi *et al.* (1976) found that water use efficiency of carrot fell with increasing water supply.

Batra and Kalloo (1991) conducted yield trial on carrot seed crop at IW: CPE 0.4, 0.8 or 1.2 and observed that water consumption increased with irrigation rate. Higher water use efficiency occurred with lowest rate of irrigation. Seed germination was not affected by any of the treatments.

Lal *et al.* (1998) revealed that one irrigation in coriander increased the yield by 117.5% while two irrigation 208.8% over no irrigation. Maximum seed yield (15.0 q/ha), consumptive use of water (328.20 mm) and water use efficiency (4.57 kg/ha/mm) in coriander were observed with four irrigations i.e. 30, 60, 90 and 120 days after sowing.

According to Pareek and Sethi (1985) while working on coriander at New Delhi reported that seed yield

increased from 9.08 q/ha (two irrigations) to 12.03 q/ha (four irrigations) Khashmelmous (1984) revealed that irrigation at 5, 8, 11 and 14 days intervals did not have significant effect on plant growth, seed yield, test weight and dry matter content of coriander.

Tomar *et al.* (1994) reported that coriander plant gave 46 percent higher seed yield when irrigated at branching, flowering and seed filling stage as compared to one irrigation applied at branching stage.

Ali *et al.* (1994) studied the effects of irrigation on seed yield of coriander under field conditions during rabi season of 1990-91 and 1991-92. They recorded highest seed yield (20.59 q/ha), net return (Rs. 21468/ha) when four irrigations were applied at early leaf, branching, flowering and seed formation stages. The cost: benefit (1:4) was highest in this treatment.

Lal *et al.* (1996) reported that beside pre-sowing irrigation, two irrigations applied at pre-flowering and during seed filling produced higher seed yield of coriander than one post sowing irrigation at six leaves or peak flowering stage.

Sharma and Prasad (1990) obtained a higher seed yield (2020 kg/ha) of fennel by irrigation at 0.6 IW/CPE than that obtained at 0.4. At 0.8 IW/CPE the yield did not increase over 0.6 IW/CPE treatment.

Yadav *et al.* (1998) while working on fennel observed that consumptive use of water, seed yield and biological yield increased with increase in number of irrigations and found highest when irrigation was applied at crown stage. They also revealed that irrigation treatment did not influence seed quality characters like germination percentage, electrical conductivity and field emergence index.

Patel *et al.* (1988) observed highest average seed yield (297 kg/ha) of fennel cv. PF–35 from plots irrigated to a depth of 60 mm at IW: CPE ratio of 0.90. Patel *et al.* (1992) recorded highest number of umbels per plant and seed yield of cumin under irrigation at 0.60 IW: CPE ratio.

Jangir and Singh (1996) obtained higher seed yield of cumin cv RZ-19 from irrigations applied at sowing, 10, 30, 55 and 80 days after sowing. Niazi and Aness (1970) while working on cumin reported that a single irrigation just before flowering increased yield by an average of 21.6 percent and an additional irrigation after flowering increased to 31.8 percent.

Shain and Calovkina (1982) recorded higher yield of fenugreek seed when soil moisture was kept at 60 to 80 percent of field capacity during bud development. Singh and Thakral (1995) at Hisar recorded the highest seed yield of fenugreek var. Pusa Early Bunching by irrigation at 1.0 IW: CPE ratio followed by 0.8 IW: CPE ratio.

2.2 Effect of fertility (nitrogen, phosphorus and potash)

Nitrogen phosphorus and potash are essential elements for nutrition of a crop and has the most pronounced effect on the vegetative growth of plant.

Excessive nitrogenous fertilizers increased top growth in carrot (Southard and Miller, 1962). In a two years trial at Ludhaina (Punjab) Dhesi (1964) found that application of 56 kg N + 56 kg K_2O/ha increased the leaf number and plant height of carrot crop. Howthorn (1952) while working on carrot seed crop has reported that 100 lbs of nitrogen per acre led to a significant increase in plant height and seed yield.

Thompson and Kalley (1957) observed that the carrot crop yielding about 280-300 q/ha removed about 32kg N, 18 kg P_2O_5 and 100 kg K_2O. They also reported that the nitrogen requirement of carrot is about 84 to 112 kg per ha.

Dhesi (1964) found that the application of fertilizers (56 kg N/ha and 56 kg of K_20/ha) significantly increased root length, root diameter and yield of carrot in sandy soils of Ludhiana.

Malik and Kanwar (1969) reported that nitrogen had highest effect on plant growth of carrot seed crop and almost each variable (plant height and number of branches) showed better response to the nitrogen. Crop responded best when nitrogen was added as 112 kg per ha.

As early as in 1953, Nilson and Fevgivist carried out experiments on carrot seed production and reported that nitrogen was the only fertilizer that produced a significant increase in seed yield.

Austin and Langdon (1969) observed significant response of nitrogen and potassium fertilizers in carrot seed yield. The highest seed yield was recorded with the application of 112 kg N, 56kg P_2O_5 and 56kg K_2O per hectare.

Malik and Kanwar (1969) found significant increase in seed yield of carrot with the application of nitrogen. Nitrogen application of 112 kg/ha improved the test weight of carrot (Malik, 1973).

Madan and Saimbhi (1986) observed that seed yield per hectare in carrot rose from 5 to 6q/ha with the increase in nitrogen rates up to 90 kg per ha but did not observe such response from P and K. Seed yield of carrot cv. Pusa Kesar was increased from 10.5 to 11.4q/ha with the increase in nitrogen from 50kg to 150kg/ha (Sharma and Singh, 1981). Potash is essential for the formation and translocation of carbohydrates and is needed in large quantity by most root crops (Thompson and Kalley, 1957).

Krarup *et al.* (1976) obtained higher carrot seed yield from plants in plots receiving 192kg N/ha.

Kumar and Nandpuri (1978) recorded highest carrot seed yield with 75kg N per ha under Ludhiana conditions. They also observed maximum number of umbels per plant at 75 kg N per ha.

Ahmed and Tanki (1989) carried out experiment on carrot seed production and reported that the highest average seed yield (17.19 q/ha) was obtained with 120kg N/ha. Phosphorus had a less pronounced effect on the seed yield. They also reported that higher levels of nitrogen caused early flowering, increased plant height, more number of secondary and tertiary umbels, increase in size of umbels and umbel weight.

Plant height, number of days to complete flowering, diameter of primary, secondary and tertiary umbels were recorded more in carrot seed crop where 80kg or more nitrogen was applied in comparison to control (Malik *et al.*, 1988).

Singh *et al.* (1994) reported that plant height, number of umbels per plant and seed yield per hectare of carrot seed crop increased with increase in nitrogen levels upto 112.5kg. A significant increase in uptake of nutrients was also observed with the application of nitrogen and phosphorus. The improvement in quality in respect of seed vigour was also obtained.

Sharma and Singh (1981) found that seed yield of carrot increased with increasing N rates from 50kg N/ha to 150kg N/ha. The carrot yield was 9.5q/ha.

Madan and Saimbhi (1986) revealed that seed yield/plant and per hectare increased with the increasing N rate upto 90kg per ha in carrot seed crop but no such response to P & K was noticed.

Rao and Maurya (1998) reported that early flowering, plant height, number of secondary umbels per plant, seed yield per plant and per ha significantly increased in carrot seed crop with increasing rate of nitrogen and these were maximum at the highest rate of 80kg N/ha. The maximum seed yield of 15.34q/ha and 12.76q/ha was obtained with the application of 80kg N/ha and 60kg P_2O_5, respectively.

Singh and Singh (1996) reported that the number of umbels per plant and seed yield of carrot increased with 150kg N and 80kg K_2O/ha. The highest seed yield of carrot was observed at the highest rate of N and K.

Pandey *et al.* (1981) found that under Haryana conditions application of 50kg nitrogen per ha gave higher seed yield of radish as compared to 30kg and 70kg per ha. However, nitrogen application at 70kg per ha had significant effect on germination of seed.

Singh *et al.* (1985) reported highest mean seed yield (10.30q/ha) with 120kg N and 50kg P_2O_5 per ha for roots and 80kg N and 60kg P_2O_5 per ha for radish seed crop.

Sharma (1991) recorded highest seed yield of good quality radish with nitrogen 80kg, phosphorus 40kg and potash 40kg/ha. Sandhu *et al.* (1985) reported best seed yield in radish from crop transplanted during second half of December and supplemented with 60kg N per ha.

Sharma (1991) observed that highest seed yield of radish was obtained by 100kg N per ha applied at 20 cm below soil surface. This treatment also gave highest number of branches per plant but did not affect test weight and germination. Similar beneficial effect of nitrogen application on plant size and branches were also observed by Sandhu *et al.* (1966) in turnip seed crop.

Yadav (1983) while working on turnip seed crop reported that application of nitrogen at the rate of 90kg per hectare resulted into maximum plant height and number of branches.

Das *et al.* (1991) found that plant height, branches per plant, number of umbels per plant, number of seeds per plant, 1000-seed weight and seed yield (90.62 cm, 5.66, 31.61, 202.6, 8.939 and 23.24 q/ha respectively) significantly increased with 40 kg N/ha and these value gradually declined with further increase in N application in coriander seed crop.

Singh and Rao (1994) while working on coriander reported that seed yield increased with higher nitrogen (36, 62, 88, 114 and 140kg/ha) and water levels (120, 240, 360, 480 and 600mm) and found highest seed yield (23.66 q/ha) from combined treatment of 480mm water along with 114kg N/ha.

2.3 Effect of plant spacing

Plant spacing has great influence on the plant growth and yield contributing parameters in vegetable crops. Krarup *et al.* (1976) while studying plant spacing in carrot seed crop (0.30, 0.50 and 0.70m) within rows with 0.80, 1.0 or 1.20m between the rows, observed highest seed yield per plant at 0.7 x 1.20m spacing and per hectare from closer spacing (0.30 x 0.80m).

Saini and Rastogi (1976) reported that in carrot closest spacing (20 x 30cm) gave higher seed yield per unit area as compared to wider spacing (40 x 60cm), but the quality of seed was better under wider spacing. Kumar and Nandpuri (1978) also found similar results. Gurr and Surina (1980) observed that closest spacing (55000 plants/ ha) advanced seed ripening by 2-3 days in carrot seed crop. As a result of close spacing seed yield per plant decreased but seed yield per hectare increased.

Gray (1981) concluded that plant density had no significant effect on height of plants, time of flowering and

test weight of seed in carrot. Sharma and Singh (1981) planted carrot stecklings *cv.* Pusa Kesar at 60 x 15 to 60 x 60 cm. The results indicated that spacing had little effect on seed yield. Gill *et al.* (1981) studied the effect of spacing on umbel order on carrot seed yield. The stecklings of carrot cv. No. 29 and S-233 were planted in early January at 40 x 30, 50 x 30 or 60 x 45cm. Plants at the widest spacing produced the largest number of umbels of different orders and these umbels produced higher seed yield per umbel than those at closer spacing. The secondary umbels produced most seeds of best quality. Seed yield per unit area increased with increasing plant density.

Malik *et al.* (1983) tried three spacings (45 x 20, 45 x 30 and 45 x 40cm) for carrot seed crop under Haryana conditions. They obtained highest seed yield when stecklings were spaced at 45 x 20 cm. Gray *et al.* (1983) found that the seed yield of carrot (Chantenay types) increased by about 50 to 55% as the plant density increased from 10 to 80 plants/ m^2. The percentage of yield contributed by the primary umbel was 25 and 62% for low and high density from 10 to 80 plants/ m^2. High density reduced the number of seeds per plant largely because of fewer umbels per plant.

Singh and Malik (1986) also recorded significantly higher carrot seed yield with plants spaced at 45 x 20cm as compared to 45 x 30cm over two years, however, they

reported that wider spacing (45 x 30cm) increased the test weight and germination percentage of main, first and second order umbel seed significantly in comparison to closer spacing (45 x 20cm). According to Lal and Pandey (1986) the highest seed yield of 1.104ton/ha was obtained from plants spaced at 30 x 30cm in comparison to other spacings tried (45 x 45cm, 60 x 60cm) under Haryana conditions.

Madan and Saimbhi (1986) reported maximum seed yield of carrot 5.5q/ ha at 45 x 20cm which was higher than 30 x 20 and 60 x 20cm spacing under Punjab conditions. Guerrero *et al.* (1986) carried out experiments on the effect of row spacing (0.62, 0.72, 0.82, 0.92m) and plant spacing (0.1, 0.2, 0.3, 0.4m) on seed production of carrot cv. Nantes. They found that distance between rows had no effect on seed yield. The yields were highest in plants sown 0.1m apart.

Oliva *et al.* (1988) found that phenological development of carrot seed crop was unaffected by plant density, but plant height increased significantly as plant density increased. The number of umbels per plant and the number of seeds per umbel declined continuously as population increased, but seed yield per unit area increased. Germination percentage and vigour was unaffected by plant density but consistently decreased from primary to tertiary umbel order. Harvest index (seed yield/ biological yield) was

highly correlated with seed quality and also useful in optimizing plant population for maximum seed yield and quality.

Noland *et al.* (1988) also reported that the highest plant density of carrot (47 plants/ m^2) produced the highest seed yield (7134kg/ha), but no consistent relationship between plant density and seed quality parameters (percent germination, speed of germination and seed weight) were found. Thus, manipulation of plant density may be used to maximize carrot seed yield and not the seed quality.

Singh *et al.* (1994) observed that low density planting of carrot resulted in more umbels per plant in first and second orders. Significant increase in seed yield/ha in each order were recorded for high density planting at spacing of 45 x 20 and 67 x 13.4cm in comparison with low density planting. High density planting in paired rows affected seed weight and vigour adversely in comparison with low density planting. The quality of seed of main and first order umbels was better than that of second order umbels.

Muhammad and Anjum (2001) while working on carrot seed production observed that plant spacing has significant effects on 1000 seed weight, root length and fresh weight of carrot seedlings. Wider spacing (45cm) proved better compared with closer spacing.

Pandey *et al.* (1981) observed that 45 x 45cm spacing in radish seed crop produced the maximum plant height and seed yield as compared to 75 x 75cm. The spacing treatment had no effect on seed germination. Brar and Kaul (1971) also found similar results.

Sharma and Lal (1991) while studying the effect of plant spacing on radish seed crop cv. Pusa Reshmi reported that maximum plant height, number of primary, secondary and tertiary branches per plant, number of pods per plant, diameter of the main shoot and seed yield per plant was recorded under 60 x 60cm plant spacing. But the seed yield per hectare was found highest with 60 x 45cm spacing.

Saharan and Baswana (1991) obtained highest number of branches, pods per plant and maximum seed yield per plant at widest spacing (60 x 75cm) in radish seed crop, while maximum seed yield per hectare was obtained by closest spacing (60 x 45cm). Jandial *et al.* (1997) reported that 30 x 30cm spacing had a significant effect on seed yield, plant height, number of branches per plant, number of pods per plant and 1000 seed weight of radish.

Yadav (1983) while conducting experiment on turnip seed crop reported that wider plant spacing (60 x 45cm) resulted in significant increase in the number of branches and number of siliqua per plant. Plant height of coriander seed crop decreased as the row spacing increased. However, number of branches per plant and number of days

to flowering were highest at 40cm row spacing. Seed yield was significantly higher at 30cm row spacing than at 20 or 40cm (Nehra *et al.*, 1998, Malav and Yadav, 1997).

Reddy and Rolston (1999) found that coriander seed yield did not differ between row spacing of 15 and 30cm, 30 and 45cm but was reduced at 60cm row spacing. However, Rahman *et al.* (1990), Bhati (1988) and Sukhadia *et al.* (1986) observed maximum seed yield in coriander at 30cm row spacing.

Yadav *et al.* (2000) reported that maximum fruit (24.16q/ha) and biological yield (136.2q/ha) of fennel were produced at 20 x 15cm spacing and minimum at 40 x 25cm spacing. Yadav and Khurana (2000) obtained maximum plant height in fennel with highest plant population, whereas primary branches and umbels per plant, number of umbellates and seeds per umbel were found maximum under the lowest plant population. Highest seed yield of fennel was obtained with the plant population of 1,33,333 plants/ha, which was statistically at par with the plant population of 1,66,666 plants/ ha as compared to 2,22,222 and 1,11,111 plants/ ha.

Pandita and Randhawa, 1994, Baswana *et al.* 1989 and Kanwar and Saimbhi, 1989 and Randhawa *et al.* (1996) observed that the highest seed yield of fenugreek was obtained when spaced at 22.5cm apart in rows.

CHAPTER - III

Materials and Methods

The investigation entitled "Studies on irrigation, fertility and spacing levels on carrot seed crop (*Daucus carrota* L.)" was conducted at the Vegetable Research Farm and Laboratories of the Department of Vegetable Science and Seed Science and Technology center of the Chaudhary Charan Singh Haryana Agricultural University, Hisar, over a period of two years (2004-05 and 2005-06).

The details of the procedures followed, criteria used for treatment evaluation and methods adopted during entire course of investigation are presented here after.

3.1 Experimental Site

The field experiment was conducted at Research Farm of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar situated in semi-arid, subtropical climate zone at 29° 10' North latitude and 75° 46' East longitude at an elevation of 215.2 meters above the mean sea level in Haryana state.

3.2 Weather and Climate

Hisar has a semi-arid climate with hot and dry desiccating winds accompanied by frequent dust storm in summer, severe cold during winter and humid warm monsoon months. The mean maximum and minimum temperature show a wide range of fluctuation during summer and winter months. Maximum temperature around 43 - 48° C during summer and temperature below freezing point accompanied by frost in winter is common in this region. The average rainfall is around 400 mm, most of which is received from south-west monsoon during July, August and September. A few showers of cyclonic rains also occur during December- January or late spring.

Meteorological data for the crop season (2004-05 and 2005-06) for maximum and minimum temperature, evaporation and total rainfall were recorded at the meteorological observatory located at Research Farm of Chaudhary Charan Singh Haryana Agricultural University, Hisar (Table 1).

Table 1: Monthly meteorological data of Hisar during 2004-05 and 2005-06

Month	2004-05			
	Av. max. Temp. (0°)	Av. min. Temp. (0°)	Av. Evp.(mm)	Total Rainfall (mm)
January	13.3	4.0	1.5	22.2
February	20.5	7.4	2.6	56.5
March	27.3	13.1	4.1	57.2
April	35.3	15.2	8.4	16.5
	2005-06			
January	20.8	4.0	2.1	0.0
February	27.4	9.9	2.3	0.0
March	27.8	11.4	3.7	27.2
April	37.0	18.0	8.3	0.0

3.3 Soil

Soil of the area is derived from Indo-Gangetic alluvium. The field selected for this investigation was uniform in fertility level and sandy loam in nature. Five primary soil samples were taken from different parts of the experimental field before sowing of the crop. A representative sample was derived from this composite sample and passed through a 2mm mesh sieve and was analysed for various physico-chemical properties of the soil (Table 2).

The data in the Table 2 indicated that the soil of the experimental field was low in nitrogen, medium in organic carbon, phosphorus and rich in potash with slightly alkaline in reaction.

Table 2: Physical and chemical composition of soil of the experimental field

Components	Soil depth (0-25 cm)		Method used
	2004-05	2005-06	
Physical analysis			
Sand (%)	70.3	70.3	International pipette
Silt (%)	17.5	16.5	method (Piper, 1950)
Clay (%)	13.1	14.6	
Chemical analysis			
Organic carbon (%)	0.47	0.46	Walkley & Black's (Piper, 1950)
Available nitrogen (kg/ha)	98.4	92.6	Alkaline Permanganate method
Available P_2O_5 (kg/ha)	22	20	(Subbiah & Asija, 1956)
Available K_2O (kg/ha)	314.6	294.5	Olsen's method (Olsen *et al.* 1954)
PH	8.1	8.15	pH meter with glass electrode
EC (ds/m at 25° C)	0.73	0.74	(Piper, 1950) Conductivity Bridge Methods

3.4 Experimental Details

3.4.1 Experiment

"Studies on irrigation, fertility and spacing levels on carrot seed crop (*Daucus car ota* L.) cv. Hisar Gairic". The experiment was laid out in a split-split-plot design with three replications during both the years. There were twenty seven treatment combinations, comprising of

three levels each of irrigation fertility and plant spacing treatments as indicated below.

Treatments

(A) Main-plot treatment

Irrigation levels : Three

(1) Irrigation at 60mm CPE (I_1)

(2) Irrigation at 90mm CPE (I_2)

(3) Irrigation at 120mm CPE (I_3)

(B) Sub-plot treatments

(a) Fertility levels : Three

(1)	60kg N/ha	30kg P_2O_5/ha	30kg K_2O/ha (F_1)
(2)	80kg N/ha	40kg P_2O_5/ha	40kg K_2O/ha (F_2)
(3)	100kg N/ha	50kg P_2O_5/ha	50kg K_2O/ha (F_3)

(b) Spacings (cm): Three

(1) 30 x 30cm (S_1)

(2) 45 x 30cm (S_2)

(3) 60 x 30cm (S_3)

3.5 Variety

In the present investigation, carrot variety Hisar Gairic was used during both the years. The seed for root crops was obtained from the Department of Vegetable Science, Chaudhary Charan Singh Haryana Agricultural University, Hisar.

$S_1F_1I_1$	$S_1F_2I_1$	$S_1F_3I_1$	$S_2F_1I_1$	$S_2F_2I_1$	$S_2F_3I_1$	$S_3F_1I_1$	$S_3F_2I_1$	$S_3F_3I_1$
IRRIGATION CHANNEL								
$S_1F_1I_2$	$S_1F_2I_2$	$S_1F_3I_2$	$S_2F_1I_2$	$S_2F_2I_2$	$S_2F_3I_2$	$S_3F_1I_2$	$S_3F_2I_2$	$S_3F_3I_2$
$S_1F_1I_3$	$S_1F_2I_3$	$S_1F_3I_3$	$S_2F_1I_3$	$S_2F_2I_3$	$S_2F_3I_3$	$S_3F_1I_3$	$S_3F_2I_3$	$S_3F_3I_3$
IRRIGATION CHANNEL								
$S_3F_3I_2$	$S_3F_1I_2$	$S_3F_2I_2$	$S_1F_3I_2$	$S_1F_1I_2$	$S_1F_2I_2$	$S_2F_3I_2$	$S_2F_1I_2$	$S_2F_2I_2$
$S_3F_3I_3$	$S_3F_1I_3$	$S_3F_2I_3$	$S_1F_3I_3$	$S_1F_1I_3$	$S_1F_2I_3$	$S_2F_3I_3$	$S_2F_1I_3$	$S_2F_2I_3$
IRRIGATION CHANNEL								
$S_3F_3I_1$	$S_3F_1I_1$	$S_3F_2I_1$	$S_1F_3I_1$	$S_1F_1I_1$	$S_1F_2I_1$	$S_2F_3I_1$	$S_2F_1I_1$	$S_2F_2I_1$
$S_2F_2I_3$	$S_2F_3I_3$	$S_2F_1I_3$	$S_3F_2I_3$	$S_3F_3I_3$	$S_3F_1I_3$	$S_1F_2I_3$	$S_1F_3I_3$	$S_1F_1I_3$
IRRIGATION CHANNEL								
$S_2F_2I_1$	$S_2F_3I_1$	$S_2F_1I_1$	$S_3F_2I_1$	$S_3F_3I_1$	$S_3F_1I_1$	$S_1F_2I_1$	$S_1F_3I_1$	$S_1F_1I_1$
$S_2F_2I_2$	$S_2F_3I_2$	$S_2F_1I_2$	$S_3F_2I_2$	$S_3F_3I_2$	$S_3F_1I_2$	$S_1F_2I_2$	$S_1F_3I_2$	$S_1F_1I_2$
IRRIGATION CHANNEL								

R_1

R_2

R_3

W

S N

E

LAYOUT PLAN OF EXPERIMENT

BUFFER

3.6 Cultural Practices

The root crop was sown on 23rd and 25th September during 2004-05 and 2005-06, respectively. Recommended package of practices regarding seed rate, sowing time, fertilizer doses and plant protection were adopted for root production. Proper aftercare was given to the crop to produce healthy roots. On 15th and 19th January in 2004-05 and 2005-06, respectively 115 and 117 days old roots were lifted and stecklings were prepared from the selected true to type roots by cutting by two-third foliage and one third root. These stecklings were then planted as per treatment in respective plots. A basal dose of half nitrogen and full dose of phosphorus and potash as per treatment was calculated and applied uniformly in respective plots before planting the steckling. The remaining half dose of nitrogen was applied one month after the steckling planting. The steklings were planted with presowing irrigation of about 8cm depth during both year. There after two common irrigation were given to each treatment and subsequent irrigation schedule was given in Table 3. Timely cultural operations were followed as and when required during the entire course of experimentation.

Table 3: Irrigation schedule of carrot seed crop during 2004-05 and 2005-06

Treatment	Date of irrigation 2004-05	Date of irrigation 2005-06
60mm (I_1)	23.3.05	13.2.06
	3.4.05	7.3.06
	9.4.05	30.3.06
	16.4.05	8.4.06
	23.4.05	15.4.06
		23.4.06
		29.4.06
Total no. of Irrigations	5	7
90mm (I_2)	29.3.05	25.2.06
	9.4.05	30.3.06
	19.4.05	12.4.06
		23.4.06
Total no. of Irrigations	3	4
120mm (I_3)	3.4.05	7.3.06
	16.4.05	8.4.06
		23.4.06
Total no. of Irrigations	2	3

3.7 Observations recorded

Observations were recorded from ten randomly selected plants from each treatment of each replication. The observations thus recorded were averaged for computation on per plant basis. The details of observations recorded are given below:

3.7.1 Growth parameters

3.7.1.1 Plant height (cm)

The height of ten tagged plants was measured from the base of plant to apex of main shoot at harvest and averaged.

3.7.1.2 Number of branches per plant at harvesting

The branches which emerged from main stem are called primary branches. All the primary branches of ten tagged plants were counted at harvest and the value was averaged to get number of branches per plant.

3.7.1.3 Number of first order umbels per plant

Number of first order umbels (emerged on primary branches) of selected ten tagged plants from each treatment in each replication were recorded at the time of harvesting and averaged.

3.7.1.4 Number of second order umbels per plant

Number of second order umbels (emerged on secondary branches) of selected ten tagged plants from each treatment in each replication were recorded at the time of harvesting and averaged.

3.7.1.5 Seed yield of main umbel per plant (g)

Main umbels (produced on main stem) from ten tagged plants were harvested separately. The umbels were then dried and threshed and seed was weighed to calculate the seed yield of main umbel per plant in gram.

3.7.1.6 Seed yield of first order umbels per plant (g)

First order umbels from ten tagged plants were harvested separately. The umbels were then dried, threshed and seed was weighed to calculate the seed yield of first order umbels per plant in gram.

3.7.1.7 Seed yield of second order umbels per plant (g)

Second order umbels from ten tagged plants were harvested separately. The umbels were then dried, threshed and seed was weighed to calculate the seed yield of second order umbels per plant in gram.

3.7.1.8 Seed yield per plant (g)

The total seed yield obtained from 10 observational plants from main, first order and second order umbels, respectively was used for computation of seed yield on plant basis in gram.

3.7.1.9 Seed yield per plot (kg)

The total seed yield of main, first order and second order umbels from all the plants including the selected plants from each plot on net plot basis was weighed separately to calculate the seed yield per plot in kilogram.

3.7.1.10 Seed yield per hectare (q/ha)

The seed yield of each plot was later converted to seed yield per hectare in quintal per hectare.

3.7.1.11 Biological yield (q/ha)

All the plants in each plot were harvested at ground level and their total biomass including umbels was weighed in each treatment in each replication and later it was converted in to biological yield per hectare in quintal per hectare.

3.7.1.12 Harvest index (%)

It is economic yield expressed as percentage of biological yield. This was calculated by using the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Seed yield}}{\text{Biological yield}} \times 100$$

3.7.1.13 Economics

The economics of each treatment was worked out on per hectare basis taking into consideration the cost of cultivation or production of crop during the years of experimentation.

3.7.2 Seed quality parameters

3.7.2.1 Test weight

From the sample drawn for each order umbel from each plot, 1000 seeds were counted each from main, first order and second order umbels and weighed to record test weight.

3.7.2.2 Standard germination percentage

One hundred seeds from each treatment were placed on the top of the paper for germination test and replicated thrice. These petri dishes were placed in germinator at 20-25° C with 90-95 percent relative humidity and final germination count was made after 14 days of sowing. The number of normal seedlings in each replication were counted and later converted into seed germination percentage.

$$\text{Std. germination percentage} = \frac{\text{Number of seed germinated}}{\text{Total number of seed sown}} \times 100$$

3.7.2.3 Vigour index

For seed vigour, seedling length (shoot length + root length) was measured and seed vigour index was calculated by multiplying seedling length to germination percent.

Seed vigour index = Seedling length (cm) x Standard germination percentage

3.7.3 Moisture studies

3.7.3.1 Consumptive use of water

The following equation was used for computing consumptive use of water. The rainfall received during the period was also added to the moisture use of the corresponding period.

$$Cu = EP \times 0.8 + \sum_{i=1}^{n} \frac{M_1 i - M_2 i}{100} \times dbi \times Di + ER$$

Where,

Cu = Consumptive use (cm) of water

EP = Pan evaporation value (mm) from USWB class A pan for the internal from date of irrigation to the date of sampling after irrigation.

0.8 = A constant factor used to get ET value by multiplying EP value for a given period.

$M_1 i$ = Percent soil moisture (oven dry method) of the layer on the day when sampling in irrigated soil is possible.

$M_2 i$ = Percent soil moisture (oven dry basis) of the i^{th} layer on date of sampling just before subsequent irrigation.

N = Number of soil layers

Dbi = Bulk density of the i^{th} soil layer (gm^{-3})

Di = Depth (cm) of the i^{th} layer of soil

ER = Effective rainfall (mm), if any during the period of consideration.

PET for the period from the date of first irrigation just after steckling planting in seed crop to the date of sampling after second common irrigation was calculated by the following equation.

$$PET = EP \times 0.8$$

Where,

PET = Potential Evapotranspiration

EP = Pan evaporation value (mm) from USWB class A pan evaporimeter for the internal from date of first irrigation to the date of sampling after second common irrigation.

0.8 = A constant factor used to get Et value by multiplying EP value for a given period.

The ground water contribution was considered nil as the water table remained below root zone during both the crop seasons in the seed crop.

Consumptive use of water was calculated for different treatments by summing up the moisture use values for different periods. The rainfall received during the period was also added to the moisture use of corresponding period.

3.7.3.2 Water use efficiency (WUE)

Water use efficiency (WUE) of different treatments was calculated by the following formula

$$WUE = \frac{\text{Yield of seed in kg/ha}}{\text{Consumptive use of water}}$$

3.8 Statistical Analysis

The data for various growth, yield and quality parameters collected during the course of investigation was statistically analysed by "Analysis of Variance" technique as described by Fisher (1950) and Cochran and Cox (1950). The significance of treatment effects was judged with the help of "F-test". Critical differences (C.D. at 5% levels) was worked out to judge the significance of differences between mean of two treatments.

CHAPTER - IV

Experimental Results

The results of the experiment conducted under the title "Studies on irrigation, fertility and spacing levels on carrot (*Daucus carota* L.) seed crop" during winter season of 2004-05 and 2005-06 are presented in this chapter.

4.1 Experiment

The experiment was conducted to evaluate the effect of irrigation, fertility and spacing levels on seed yield and seed quality of carrot var. Hisar Gairic.

4.1.1 Growth and yield characters

4.1.1.1 Plant height at seed harvest

The data on plant height in Table 4 revealed that maximum plant height (145.83cm during 2004-05 and 137.72cm during 2005-06) was recorded when the crop was irrigated at 60mm CPE (I_1). Minimum plant height of 128.58 cm in 2004-05 and 118.95cm during 2005-06 was observed when crop was irrigated at 120mm CPE in I_3 treatment.

Fertility levels also significantly influenced the plant height during both the years. Highest plant height (140.55cm in 2004-05) was observed with 100kg N, 50kg

Table 4: Effect of irrigation, fertility and spacing on plant height (cm) at harvest in carrot

Treatment	2004-05	2005-06
Irrigation levels (CPE)		
I_1 (60mm)	145.83	137.72
I_2 (90mm)	140.73	129.03
I_3 (120mm)	128.58	118.95
CD at 5%	3.98	4.72
Fertility levels (N:P:Kkg/ha)		
F_1 (60:30:30)	136.10	126.12
F_2 (80:40:40)	138.49	127.50
F_3 (100:50:50)	140.55	132.08
CD at 5%	1.53	2.26
Spacing (cm)		
S_1 (30 x 30)	139.34	127.71
S_2 (45 x 30)	138.43	128.43
S_3 (60 x 30)	137.37	129.55
CD at 5%	N.S.	N.S.

P_2O_5 and 50kg K_2O per ha (F_3 treatment) fertility treatment which was followed by application of 80kg N, 40kg P_2O_5 and 40kg K_2O per ha (F_2) and the minimum (126.12cm in 2005-06) height was recorded with 60kg N, 30kg P_2O_5 and 30kg K_2O per ha (F_1). No significant difference was observed under different levels of spacing on plant height during both the years of experimentation.

Interaction between irrigation and fertility was found significant with regard to plant height at harvest during 2004-05 (Table 5). Plant height increased with the increase in irrigation and fertility levels. Maximum plant height (148.41cm) was recorded with I_1F_3 treatment combination closely followed by I_1F_2 and was at par. The lowest (127.55cm) plant height was found with treatment combination I_3F_2 which was statistical at par with I_3F_1 treatment.

4.1.1.2 Branches per plant at harvest

The effect on number of branches per plant as affected by various treatments is presented in Table 6. Maximum branches (7.25 during 2004-05 and 6.76 during 2005-06) were recorded in the crop when irrigated at 60mm CPE (I_1) during both the years. The minimum branches (6.32 during 2004-05 and 5.81 during 2005-06) were recorded when crop was irrigated at 120 mm CPE (I_3) in each year.

Table 5: Interactive effect of irrigation and fertility on plant height (cm) at seed harvest during 2004-05

Treatment	Fertility levels (N:P:K kg/ha)			
	F_1 (60:30:30)	F_2 (80:40:40)	F_3 (100:50:50)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	142.69	146.38	148.41	145.83
I_2 (90mm)	138.02	141.55	142.63	140.73
I_3 (120mm)	127.59	127.55	130.59	128.58
Mean	136.10	138.49	140.55	

CD at 5%

1. Irrigation = 3.98
2. Fertility = 1.53
3. Irrigation x Fertility = 2.65

Table 6: Effect of irrigation, fertility and spacing on number of branches per plant at harvest in carrot.

Treatment	2004-05	2005-06
Irrigation levels (CPE)		
I_1 (60mm)	7.25	6.76
I_2 (90mm)	6.61	6.17
I_3 (120mm)	6.32	5.81
CD at 5%	0.26	0.25
Fertility levels (N:P:K kg/ha)		
F_1 (60:30:30)	6.61	6.13
F_2 (80:40:40)	6.72	6.22
F_3 (100:50:50)	6.85	6.39
CD at 5%	0.15	0.13
Spacing (cm)		
S_1 (30 x 30)	6.62	6.12
S_2 (45 x 30)	6.77	6.26
S_3 (60 x 30)	6.80	6.36
CD at 5%	0.15	0.13

Fertility levels also influenced branches per plant significantly during both the seasons. Branches per plant increased with each increase in fertility level. Maximum branches (6.85 in 2004-05 and 6.39 in 2005-06) were observed at higher fertility level (F_3). The minimum (6.13 in 2005-06) branches per plant were recorded in F_1 fertility treatment. The branches per plant in F_1 and F_2 treatment of fertility were found statistically at par. Different spacing levels also significantly affected the number of branches per plant. Wider spacing (60x30cm) produced greater number of branches (6.80 in 2004-05 and 6.36 in 2005-06) per plant as compared to closer spacing (30x30cm) which produced 6.62 branches during first year and 6.12 during second year. S_2 (45 x 30cm) and S_3 (60 x 30cm) treatment of spacing produced statistically similar number of branches per plant. Interaction effect of irrigation and fertility on number of branches per plant was found significant during both the years (Table 7). Minimum number of branches (6.26 in 2004-05 and 5.75 in 2005-06) were found is I_3F_2 treatment during both the growing seasons. However, maximum number of branches (7.55 in first and 7.06 in second year) per plant were recorded by irrigating the crop at 60mm CPE (I_1) and by applying highest fertility dose (F_3) during each season.

Table 7: Interactive effect of irrigation and fertility on number of branches. per plant at harvest during 2004-05 and 2005-06

Treatment	Fertility levels (N:P:K kg/ha) (2004-05)			
	F_1 (60:30:30)	F_2 (80:40:40)	F_3 (100:50:50)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	7.01	7.20	7.55	7.25
I_2 (90mm)	6.53	6.69	6.61	6.61
I_3 (120mm)	6.30	6.26	6.39	6.32
Mean	6.61	6.72	6.85	

Treatment	Fertility levels (N:P:K kg/ha) (2005-06)			
	F_1 (60:30:30)	F_2 (80:40:40)	F_3 (100:50:50)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	6.52	6.70	7.06	6.76
I_2 (90mm)	6.09	6.19	6.22	6.17
I_3 (120mm)	5.80	5.75	5.89	5.81
Mean	6.13	6.22	6.39	

CD at 5%	Irrigation	Fertility	Irrigation x Fertility
2004-05	0.26	0.15	0.26
2005-06	0.25	0.13	0.23

4.1.1.3 Number of first order umbels per plant

Each irrigation levels significantly affected the number of first order umbels per plant (Table 8). Highest number of first order umbels per plant (8.46 during 2004-05 and 7.84 during 2005-06) were recorded in I_1 irrigation treatment. While lowest (6.11 in first and 5.91 in second year) number of first order umbels were recorded in I_3 irrigation treatment.

F_3 (100kg N, 50kg P_2O_5 and 50kg K_2O per ha) fertility level produced highest (7.29 in 2004-05 and 6.96 in 2005-06) number of first order umbels per plant during both the years of investigation. These were found statistically at par in (F_1 and F_2) and (F_2 and F_3) fertility levels during 2004-05. Effect of spacing on number of first order umbels per plant was not found significant in any of the two years of experimentation.

Data presented in Table 9 indicated that first order umbels per plant were significantly affected by irrigation x fertility interaction in 2004-05. Highest (8.77) number of first order umbels were recorded in I_1F_3 treatment, while lowest (6.04) were received from I_3F_1 treatment which were statistical at par with I_3F_2 and I_3F_3 treatment (6.11 and 6.18, respectively). First order umbels in I_2F_1, I_2F_2 and I_2F_3 were also at par with each other (6.78, 6.93 and 6.92, respectively).

Table 8: Effect of irrigation, fertility and spacing on number of first order umbels per plant in carrot

Treatment	2004-05	2005-06
Irrigation levels (CPE)		
I_1 (60mm)	8.46	7.84
I_2 (90mm)	6.88	6.68
I_3 (120mm)	6.11	5.91
CD at 5%	0.09	0.23
Fertility levels (N:P:K kg/ha)		
F_1 (60:30:30)	7.00	6.72
F_2 (80:40:40)	7.16	6.41
F_3 (100:50:50)	7.29	6.96
CD at 5%	0.17	0.18
Spacing (cm)		
S_1 (30 x 30)	7.04	6.73
S_2 (45 x 30)	7.15	6.81
S_3 (60 x 30)	7.26	6.89
CD at 5%	NS	NS

Table 9: Interactive effect of irrigation and fertility on number of first order umbels per plant at harvest during 2004-05

Treatment	Fertility levels (N:P:K kg/ha) (2004-05)			
	F_1 (60:30:30)	F_2 (80:40:40)	F_3 (100:50:50)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	8.17	8.43	8.77	8.46
I_2 (90mm)	6.78	6.93	6.92	6.88
I_3 (120mm)	6.04	6.11	6.18	6.11
Mean	7.00	7.16	7.29	

CD at 5%	Irrigation	Fertility	Irrigation x Fertility
	0.09	0.17	0.30

4.1.1.4 Number of second order umbels per plant

Data presented in Table 10 indicated that lowest number of second order umbels per plant (11.95 during 2004-05 and 10.99 during 2005-06) were observed with I_3 irrigation treatment while maximum umbels (15.68 in 2004-05 and 14.63 in 2005-06) were recorded in I_1 irrigation treatment during the two years.

Each fertility level also affected umbels per plant of second order. Second order umbels increased with each increase in fertility level and highest were recorded with F_3 fertility level during both seasons (14.23 in 2004-05 and 13.29 in 2005-06) while lowest (13.71 in first and 12.69 in second year) were recorded when plants were supplied with F_1 fertility level. The effect of F_2 and F_3 treatments in the year 2004-05 were statistically similar with respect to production of second order umbels per plant.

Spacing also directly affected the second order umbels per plant and its numbers increased with wider spacing i.e. in S_3 (14.17 in 2004-05 and 13.13 in 2005-06) while closer spacing (S_1) produced 13.88 second order umbels in first and 12.83 in second year, respectively. No significant differences were observed for production of second order umbels in S_1 (30 x 30 cm) and S_2 (45 x 30cm) and between S_2 and S_3 treatments in the two years of experimentation.

Table 10: Effect of irrigation, fertility and spacing on number of second order umbels per plant in carrot

Treatment	2004-05	2005-06
Irrigation levels (CPE)		
I_1 (60mm)	15.68	14.63
I_2 (90mm)	14.34	13.30
I_3 (120mm)	11.95	10.99
CD at 5%	0.35	0.47
Fertility levels (N:P:K kg/ha)		
F_1 (60:30:30)	13.71	12.69
F_2 (80:40:40)	14.04	12.94
F_3 (100:50:50)	14.23	13.29
CD at 5%	0.27	0.27
Spacing (cm)		
S_1 (30 x 30)	13.88	12.83
S_2 (45 x 30)	13.93	12.96
S_3 (60 x 30)	14.17	13.13
CD at 5%	0.27	0.27

4.1.15 Seed yield of main umbel per plant

Data present in Table 11 indicated that per plant seed yield of main umbel was significantly affected by each irrigation level. Maximum (6.18g in 2004-05 and 5.95g in 2005-06) seed yield per plant in main umbel was observed when the crop was irrigated at 60 mm CPE (I_1) while lowest seed yield of main umbel per plant was recorded by irrigating the crop at 120 mm CPE (I_3).

Per plant seed yield in main umbel increased with each increase in fertility level during both the years. Minimum (5.45g during 2004-05 and 5.25g during 2005-06) seed yield of main umbel per plant was found when crop was given lowest fertility level i.e. 60kg N, 30kg P_2O_5 and 30kg K_2O/ha (F_1) while maximum (5.86g in first and 5.62g in second year) seed yield of main umbel per plant was recorded under highest fertility level (F_3) during the two seasons. However, F_1 and F_2 were statistically at par during both the years. Various plant spacing could not significantly affect the seed yield of main umbel per plant. Interaction effect pertaining to seed yield of main umbel per plant between irrigation and fertilizer in both the years have been presented in Table 12. The table revealed that the seed yield of main umbel per plant was found highest (6.42g in 2004-05 and 6.12g in 2005-06) when the crop was irrigated at 60 mm CPE (I_1) treatment and when F_3 (100kg N, 50kg P_2O_5 and 50kg

Table 11: Effect of irrigation, fertility and spacing on seed yield (g) of main umbel per plant in carrot

Treatment	2004-05	2005-06
Irrigation levels (CPE)		
I_1 (60mm)	6.18	5.95
I_2 (90mm)	5.59	5.39
I_3 (120mm)	5.15	4.95
CD at 5%	0.03	0.12
Fertility levels (N:P:K kg/ha)		
F_1 (60:30:30)	5.45	5.25
F_2 (80:40:40)	5.61	5.41
F_3 (100:50:50)	5.86	5.62
CD at 5%	0.16	0.18
Spacing (cm)		
S_1 (30 x 30)	5.54	5.31
S_2 (45 x 30)	5.64	5.44
S_3 (60 x 30)	5.74	5.54
CD at 5%	NS	NS

Table 12: Interactive effect of irrigation and fertility on seed yield (g) of main umbel per plant during 2004-05 and 2005-06

Treatment	Fertility levels (N:P:K kg/ha) (2004-05)			
	F_1 (60:30:30)	F_2 (80:40:40)	F_3 (100:50:50)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	5.95	6.16	6.42	6.18
I_2 (90mm)	5.44	5.58	5.75	5.59
I_3 (120mm)	4.95	5.10	5.41	5.15
Mean	5.45	5.61	5.86	

Treatment	Fertility levels (N:P:K kg/ha) (2005-06)			
	F_1 (60:30:30)	F_2 (80:40:40)	F_3 (100:50:50)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	5.75	5.97	6.12	5.95
I_2 (90mm)	5.25	5.38	5.52	5.39
I_3 (120mm)	4.76	4.88	5.52	4.95
Mean	5.25	5.41	5.62	

CD at 5%	Irrigation	Fertility	Irrigation x Fertility
2004-05	0.03	0.16	0.28
2005-06	0.12	0.18	0.31

K_2O/ha) dose of fertilizer was applied. The seed yield in I_1F_2 treatment combination was also found statistically similar to that of I_1F_3 treatment. The F_2 and F_3 fertility level gave statistically at par yield in both the years under I_2 (90 mm CPE) irrigation level.

4.1.1.6 Seed yield of first order umbels per plant

The effect on seed yield of first order umbels per plant as affected by different irrigation, fertility and spacing levels is presented in Table 13. Highest seed yield of first order umbel per plant (18.19g in 2004-05 and 17.15g in 2005-06) were recorded in the crop when irrigation was applied at 60mm CPE (I_1) during both the seasons. While lowest seed yield (14.75g during first year and 13.67g during 2005-06) of first order umbel per plant was obtained by irrigating the crop at 120mm CPE (I_3). Regarding fertility levels, F_3 (100kg N, 50kg P_2O_5 and 50kg K_2O/ha) dose of fertilizer produced maximum (16.72g in 2004-05 and 15.63g in 2005-06) seed yield of first order umbels per plant, while lowest seed yield (16.14g in first 15.07g in second year) per plant was obtained in F_1 (60kg N, 30kg P_2O_5 and 30kg K_2O/ha) level of fertilizer. Various spacings also affected per plant seed yield in first order umbels significantly. S_3 (60x30cm) spacing produced maximum (16.65g in 2004-05 and 15.55g in 2005-06) seed yield in first order umbel, while minimum (16.22g in 2004-05) seed per plant was produced

Table 13: Effect of irrigation, fertility and spacing on seed yield (g) of first order umbels per plant in carrot

Treatment	2004-05	2005-06
Irrigation levels (CPE)		
I_1 (60mm)	18.19	17.15
I_2 (90mm)	16.40	15.31
I_3 (120mm)	14.75	13.67
CD at 5%	0.11	0.13
Fertility levels (N:P:K kg/ha)		
F_1 (60:30:30)	16.14	15.07
F_2 (80:40:40)	16.48	15.43
F_3 (100:50:50)	16.72	15.63
CD at 5%	0.18	0.14
Spacing (cm)		
S_1 (30 x 30)	16.22	15.18
S_2 (45 x 30)	16.47	15.40
S_3 (60 x 30)	16.65	15.55
CD at 5%	0.18	0.14

in S_1 (30x30cm) spacing. The S_2 and S_3 spacings were statistically at par during 2004-05. The interaction between irrigation and fertility during the two years of investigation with regard to seed yield of first order umbels per plant was found significant (Table 14). Maximum per plant seed yield in first order umbels was found in I_1F_3 treatment combination followed by I_1F_2, while minimum seed yield in first order umbels per plant was recorded in I_3F_1 during the two years of investigations.

4.1.1.7 Seed yield of second order umbels per plant

Seed yield of second order umbels per plant is presented in Table 15. The perusal of data showed that per plant seed yield of second order umbels increased significantly with the increase in irrigation frequency. Maximum (2.43g in first and 1:95g in second year) seed yield per plant in second order umbels was recorded in I_1 (60 mm CPE) irrigation regime during both the years of investigation which was followed by I_2 and, the minimum (1.14g in 2004-05 and 0.61g in 2005-06) seed yield in second order umbels per plant was recorded in I_3 moisture regime. Among the different fertility levels F_3 produced maximum (1.99g in first and 1.52g in second year) seed yield per plant in second order umbels closely followed by F_2 during 2004-05. The lowest (F_1) fertility gave minimum seed yield of second order umbels per plant. The widest (60 x 30cm) spacing produced

Table 14: Interactive effect of irrigation and fertility on seed yield (g) per plant of first order umbels during 2004-05 and 2005-06

Treatment	Fertility levels (N:P:K kg/ha) (2004-05)			
	F_1 (60:30:30)	F_2 (80:40:40)	F_3 (100:50:50)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	17.70	18.26	18.62	18.19
I_2 (90mm)	16.13	16.44	16.64	16.40
I_3 (120mm)	14.59	14.74	14.91	14.75
Mean	16.14	16.48	16.72	

Treatment	Fertility levels (N:P:K kg/ha) (2005-06)			
	F_1 (60:30:30)	F_2 (80:40:40)	F_3 (100:50:50)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	16.64	17.29	17.52	17.15
I_2 (90mm)	15.05	15.35	15.51	15.31
I_3 (120mm)	13.51	13.64	13.86	13.67
Mean	15.07	15.43	15.63	

CD at 5%	Irrigation	Fertility	Irrigation x Fertility
2004-05	0.11	0.14	0.25
2005-06	0.13	0.18	0.31

Table 15: Effect of irrigation, fertility and spacing on seed yield (g) of second order umbels per plant in carrot

Treatment	2004-05	2005-06
Irrigation levels (CPE)		
I_1 (60mm)	2.43	1.95
I_2 (90mm)	2.20	1.70
I_3 (120mm)	1.14	0.61
CD at 5%	0.08	0.15
Fertility levels (N:P:K kg/ha)		
F_1 (60:30:30)	1.86	1.35
F_2 (80:40:40)	1.93	1.39
F_3 (100:50:50)	1.99	1.52
CD at 5%	0.06	0.07
Spacing (cm)		
S_1 (30 x 30)	1.89	1.37
S_2 (45 x 30)	1.92	1.42
S_3 (60 x 30)	1.96	1.46
CD at 5%	0.06	0.07

maximum seed yield per plant in the two years of investigation which was significantly superior over S_1 (30 x 30 cm) spacing treatment. The per plant seed yield was statistically at par in S_1, S_2 and S_2, S_3 treatments in each years of experimentation. The interaction table 16 reveals that the maximum (2.19g) seed yield per plant was obtained in I_1F_3 treatment combinations.

4.1.1.8 Total seed yield per plant

The highest total seed yield per plant (26.80g in first and 25.05g in second year) was observed in I_1 irrigation level which was followed by I_2 (Table 17). The minimum seed yield (21.04g in 2004-05 and 19.23g in 2005-06) per plant seed yield was found in I_3 level of irrigation. Regarding fertility, F_3 fertility treatment produced maximum quantity of total seed yield per plant, while the minimum was produced in F_1 treatment of fertility. Various spacing treatments had no significant effect on total seed yield per plant.

4.1.1.9 Total seed yield per plot and quintals/ha

The data regarding seed yield (kg) per plot and q/ha is presented In Table 18 to 21. The data clearly shows that maximum seed yield (11.22q/ha during first and 10.06q/ha during second year of studies) was harvested in I_1 irrigation at 60mm CPE treatment, which was closely followed by I_2 and was statistically at par. Minimum seed yield (8.19q/ha in first and 7.93q/ha in second year) was

Table 16: Interactive effect of irrigation and fertility on seed yield (g) per plant of second order umbels during 2005-06

Treatment	Fertility levels (N:P:K kg/ha) 2005-06			
	F_1 (60:30:30)	F_2 (80:40:40)	F_3 (100:50:50)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	1.76	1.90	2.19	1.95
I_2 (90mm)	1.69	1.69	1.73	1.70
I_3 (120mm)	0.59	0.58	0.64	0.61
Mean	1.35	1.39	1.52	

CD at 5%	Irrigation	Fertility	Irrigation × Fertility
2005-06	0.15	0.07	0.12

Table 17: Effect of irrigation, fertility and spacing on total seed yield (g) per plant in carrot

Treatment	2004-05	2005-06
Irrigation levels (CPE)		
I_1 (60mm)	26.80	25.05
I_2 (90mm)	24.19	22.40
I_3 (120mm)	21.04	19.23
CD at 5%	0.19	0.39
Fertility levels (N:P:K kg/ha)		
F_1 (60:30:30)	23.45	21.67
F_2 (80:40:40)	24.02	22.23
F_3 (100:50:50)	24.57	22.77
CD at 5%	0.43	0.47
Spacing (cm)		
S_1 (30 x 30)	23.65	21.86
S_2 (45 x 30)	24.03	22.26
S_3 (60 x 30)	24.35	22.55
CD at 5%	NS	NS

Table 18: Effect of irrigation, fertility and spacing on seed yield (kg) per plot in carrot

Treatment	2004-05	2005-06
Irrigation levels (CPE)		
I_1 (60mm)	2.55	2.49
I_2 (90mm)	2.43	2.31
I_3 (120mm)	2.08	1.76
CD at 5%	0.09	0.03
Fertility levels (N:P:K kg/ha)		
F_1 (60:30:30)	2.32	2.03
F_2 (80:40:40)	2.34	2.20
F_3 (100:50:50)	2.41	2.33
CD at 5%	0.07	0.06
Spacing (cm)		
S_1 (30 x 30)	3.04	2.65
S_2 (45 x 30)	2.23	2.20
S_3 (60 x 30)	1.79	1.71
CD at 5%	0.07	0.06

Table 19: Interactive effect of irrigation and fertility on seed yield (kg) per plot during 2004-05 and 2005-06

Treatment	Fertility levels (N:P:K kg/ha) (2004-05)			
	F_1 (60:30:30)	F_2 (80:40:40)	F_3 (100:50:50)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	2.44	2.53	2.68	2.55
I_2 (90mm)	2.45	2.41	2.44	2.43
I_3 (120mm)	2.06	2.08	2.12	2.43
Mean	2.32	2.34	2.41	2.08

Treatment	Fertility levels (N:P:K kg/ha) (2005-06)			
	F_1 (60:30:30)	F_2 (80:40:40)	F_3 (100:50:50)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	2.35	2.50	2.62	2.49
I_2 (90mm)	2.14	2.32	2.46	2.31
I_3 (120mm)	1.60	1.78	1.91	1.76
Mean	2.03	2.20	2.33	

CD at 5%	Irrigation	Fertility	Irrigation x Fertility
2004-05	0.09	0.07	0.12
2005-06	0.03	0.06	0.10

Table 20: Interactive effect of irrigation and spacing on seed yield (kg) per plot during 2005-06

Treatment	Spacing (2005-06)			
	S_1 (30x30cm)	**S_2 (45x30cm)**	**S_3 (60x30cm)**	**Mean**
Irrigation levels (CPE)				
I_1 (60mm)	3.00	2.55	1.92	2.49
I_2 (90mm)	2.80	2.34	1.78	2.31
I_3 (120mm)	2.15	1.71	1.42	1.76
Mean	2.65	2.20	1.71	

CD at 5%	Irrigation	Spacing	Irrigation x Spacing
2005-06	0.03	0.06	0.10

Table 21: Effect of irrigation, fertility and spacing on seed yield (q/ha) in carrot

Treatment	2004-05	2005-06
Irrigation levels (CPE)		
I_1 (60mm)	11.22	10.06
I_2 (90mm)	10.38	9.58
I_3 (120mm)	8.19	7.93
CD at 5%	0.88	0.83
Fertility levels (N:P:K kg/ha)		
F_1 (60:30:30)	9.14	8.95
F_2 (80:40:40)	9.90	9.35
F_3 (100:50:50)	10.49	9.54
CD at 5%	0.77	0.82
Spacing (cm)		
S_1 (30 x 30)	12.02	11.36
S_2 (45 x 30)	10.01	8.82
S_3 (60 x 30)	7.77	7.06
CD at 5%	0.77	0.82

harvested in I_3 (120mm CPE) irrigation regime. Various fertility and spacing levels also significantly influenced the total seed yield. The F_3 (100kg N, 50kg P_2O_5 and 50kg K_2O per ha) level of fertility produced significantly higher seed yield (q/ha) over F_1 (60kg N, 30kg P_2O_5 and 30kg K_2O per ha) fertility treatment. No significant difference regarding seed yield (q/ha) were observed between F_1, F_2 and F_3, F_2 level of fertility. Like irrigation and fertility spacing too significantly affected the total seed yield (q/ha). The maximum seed yield (12.02q/ha) was observed under the closest i.e. S_1 spacing (30 x 30cm), while the minimum (7.06 q/ha) being found in widest spacing (60 x 30cm).

The interaction between irrigation x fertility and irrigation x spacing was found significant. If we look at the interaction Table 22, we found that maximum seed yield (11.81 q/ha) was recorded in I_1F_3 treatment combinations closely followed by I_1F_2, I_2F_3 and I_2F_2 which were statistically at par in 2004-05. In second year 2005-06 the interaction of I_1 and I_2 with all fertility levels were maximum and at par. Regarding interaction between irrigation and spacing in Table 23, the maximum seed yield (13.52q/ha) was observed in I_1S_1 treatment combination followed by I_2S_1 (12.60q/ha) while minimum seed yield (6.66q/ha) was found in I_3S_3 combination followed by I_3S_2 and I_2S_3.

Table 22: Interactive effect of irrigation and fertility on seed yield (q/ha) during 2004-05 and 2005-06

Treatment	Fertility levels (N:P:K kg/ha) (2004-05)			
	F_1 (60:30:30)	F_2 (80:40:40)	F_3 (100:50:50)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	10.58	11.27	11.81	11.22
I_2 (90mm)	9.62	10.44	11.08	10.38
I_3 (120mm)	7.21	8.00	8.58	7.93
Mean	9.14	9.90	10.49	

Treatment	Fertility levels (N:P:K kg/ha) (2005-06)			
	F_1 (60:30:30)	F_2 (80:40:40)	F_3 (100:50:50)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	9.70	10.10	10.40	10.06
I_2 (90mm)	9.35	9.63	9.76	9.58
I_3 (120mm)	7.79	8.32	8.46	8.19
Mean	8.95	9.35	9.54	

CD at 5%	Irrigation	Fertility	Irrigation x Fertility
2004-05	0.88	0.77	1.46
2005-06	0.83	0.82	1.56

Table 23: Interactive effect of irrigation and spacing on seed yield (q/ha). during 2004-05

Treatment	Spacing (2004-05)			
	S_1 (30x30cm)	**S_2 (45x30cm)**	**S_3 (60x30cm)**	**Mean**
Irrigation levels (CPE)				
I_1 (60mm)	13.52	11.50	8.65	11.22
I_2 (90mm)	12.60	10.54	7.99	10.38
I_3 (120mm)	9.93	7.98	6.66	8.19
Mean	12.02	10.01	7.77	

CD at 5%	Irrigation	Spacing	Irrigation x Spacing
2004-05	0.88	0.77	1.46

4.1.1.10 Biological yield

The data pertaining to biological yield have been presented in Table 24. The data revealed that biological yield was found highest (97.99 q/ha in 2004-05 and 78.13 q/ha in 2005-06) when crop was irrigated at 60mm CPE (I_1) which was significantly superior over I_3 irrigation treatment. The minimum (64.88q/ha in 2005-06) biological yield was recorded under I_3 treatment. Biological yield of I_1 and I_2 irrigation treatment was statistically at par.

Among various fertility levels, biological yield was recorded highest under F_3 fertility level as compared to lower (F_1) level of fertility during both the seasons. The biological yield of F_1 and F_2 treatments was found at par during both the cropping seasons. Amongst various spacings, significantly highest biological yield (102.60q/ha) was recorded in S_1 (30 x 30cm) treatment while minimum in S_3 (60 x 30cm) treatment. The interaction effect of irrigation x fertility and fertility x spacing was found significant in production of biological yield of seed crop. The interaction between irrigation and fertility (Table 25) shows that maximum biological yield was produced in I_1F_3 treatment closely followed by and at par in I_1F_2 and I_2F_3 but minimum in I_3F_1 treatment. The interaction between fertility and spacing (Table 26) was found significant in 2005-06 and highest biological yield (87.51q/ha) was produced under S_1F_3

Table 24: Effect of irrigation, fertility and spacing on Biological yield (q/ha) in carrot

Treatment	2004-05	2005-06
Irrigation levels (CPE)		
I_1 (60mm)	97.99	78.13
I_2 (90mm)	92.34	72.32
I_3 (120mm)	84.99	64.88
CD at 5%	8.87	6.61
Fertility levels (N:P:K kg/ha)		
F_1 (60:30:30)	88.59	68.61
F_2 (80:40:40)	91.51	71.43
F_3 (100:50:50)	95.22	75.28
CD at 5%	4.48	4.07
Spacing (cm)		
S_1 (30 x 30)	102.60	82.69
S_2 (45 x 30)	92.77	72.72
S_3 (60 x 30)	79.94	59.92
CD at 5%	4.48	4.07

Table 25: Interactive effect of irrigation and fertility on biological yield (q/ha) during 2004-05 and 2005-06

Treatment	Fertility levels (N:P:K kg/ha) (2004-05)			
	F_1 (60:30:30)	F_2 (80:40:40)	F_3 (100:50:50)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	94.09	97.12	102.76	97.99
I_2 (90mm)	89.04	92.60	95.37	92.34
I_3 (120mm)	82.63	84.83	87.51	84.99
Mean	88.59	91.51	95.22	

Treatment	Fertility levels (N:P:K kg/ha) (2005-06)			
	F_1 (60:30:30)	F_2 (80:40:40)	F_3 (100:50:50)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	74.29	77.15	82.93	78.13
I_2 (90mm)	68.89	72.55	75.53	72.32
I_3 (120mm)	62.64	64.59	67.39	64.88
Mean	68.61	71.43	75.28	

CD at 5%	Irrigation	Fertility	Irrigation x Fertility
2004-05	6.87	4.48	8.55
2005-06	6.61	4.07	8.26

Table 26: Interactive effect of fertility and spacing on biological yield (q/ha) during and 2005-06

Treatment	Spacing (2005-06)			
	S_1 (30x30cm)	**S_2 (45x30cm)**	**S_3 (60x30cm)**	**Mean**
Fertility levels (N:K:Kg/ha)				
F_1 (60:30:30)	78.12	70.40	57.31	68.61
F_2 (80:40:40)	82.44	72.03	59.83	71.43
F_3 (100:50:50)	87.51	75.72	62.63	75.28
Mean	82.69	72.72	59.92	

CD at 5%	Fertility	Spacing	Irrigation x Spacing
2004-05	4.07	4.07	8.26

and S_1F_2 treatment which were statistically at par. The minimum biological yield (57.31q/ha) was recorded under S_3F_1 treatment followed by S_3F_2 and S_3F_3 which were statistically at par.

4.1.1.11 Harvest index

Harvest index of crop was found maximum (12.28% during 2004-05 and 14.29% during 2005-06) in irrigation level at (I_1) 60mm CPE during both the years (Table 27). It was found statistical at par (12.11 in 2004-05 and 14.25 in 2005-06) with irrigation level of 90mm CPE (I_2).

Various fertility levels also showed significant effect on harvest index. Minimum harvest index (10.21%) was observed in 2004-05 by applying F_1 level of fertilizer. Highest harvest index (13.84% in 2005-06) was recorded with F_3 treatment of fertility i.e. highest fertility level but it was statistical at par with F_2 treatment i.e. medium fertility level during both the years. Different spacings also showed effect on harvest index significantly during 2005-06 only. Harvest index was recorded maximum (14.38%) when stecklings were spaced at 30x30cm (S_1) followed by 45x30cm (S_2) spacing. The minimum (12.80%) harvest index was observed at the widest spacing i.e. 60x30cm (S_3).

Significant interaction of irrigation x fertility level was observed on harvest index during 2004-05 and 2005-06 (Table 28). Maximum (14.63%) harvest index was recorded

Table 27: Effect of irrigation, fertility and spacing on Harvest Index (%) in carrot

Treatment	2004-05	2005-06
Irrigation levels (CPE)		
I_1 (60mm)	12.28	14.29
I_2 (90mm)	12.11	14.25
I_3 (120mm)	7.41	12.19
CD at 5%	0.43	0.50
Fertility levels (N:P:K kg/ha)		
F_1 (60:30:30)	10.21	13.17
F_2 (80:40:40)	10.68	13.71
F_3 (100:50:50)	10.91	13.84
CD at 5%	0.32	0.35
Spacing (cm)		
S_1 (30 x 30)	11.51	14.38
S_2 (45 x 30)	10.63	13.55
S_3 (60 x 30)	9.66	12.80
CD at 5%	NS	0.35

Table 28: Interactive effect of irrigation and fertility on harvest index (%) during 2004-05 and 2005-06

Treatment	Fertility levels (N:P:K kg/ha) (2004-05)			
	F_1 (60:30:30)	F_2 (80:40:40)	F_3 (100:50:50)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	12.10	12.42	12.31	12.28
I_2 (90mm)	11.73	12.12	12.49	12.11
I_3 (120mm)	6.8	7.49	7.94	7.41
Mean	10.21	10.68	10.91	

Treatment	Fertility levels (N:P:K kg/ha) (2005-06)			
	F_1 (60:30:30)	F_2 (80:40:40)	F_3 (100:50:50)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	14.21	14.51	14.15	14.29
I_2 (90mm)	13.84	14.26	14.63	14.25
I_3 (120mm)	11.47	12.35	12.74	12.19
Mean	13.17	13.71	13.84	

CD at 5%	Irrigation	Fertility	Irrigation x Fertility
2004-05	0.43	0.32	0.55
2005-06	0.50	0.35	0.60

with I_2F_3 treatment in 2005-06, it was statistical at par with treatments I_1F_1, I_1F_2, I_1F_3 and I_2F_2 during both the years.

Significant interaction of irrigation x spacing with regard to harvest index was recorded during both years (Table 29). It was lowest (6.88% in 2004-05 and 11.81% in 2005-06) with treatments I_3S_3 and I_3S_2 respectively in both seasons. However, it was statistically at par with I_3S_2 in 2004-05 and I_3S_3 in 2005-06. Harvest index was observed maximum (15.39% in second year) when crop was irrigated at 60mm CPE (I_1) and stecklings were spaced at 30x30cm (S_1) which was statistically at par with I_2S_1 treatment combination.

4.1.2 Seed quality characters

4.1.2.1 Test weight of main umbel, first order and second order umbel

Data recorded on test weight is presented in Table 30. Test weight of main umbel, first order and second order umbels was significantly affected by different levels of irrigation, fertility and spacing. The test weight of various order umbels was recorded maximum in the wettest moisture regime i.e. in I_1 (irrigation at 60mm CPE) followed by I_2. The minimum test weight of each order umbel seed was observed in I_3 (irrigation at 120mm CPE), the driest moisture regime. Among the various fertility levels, the test weight of various order umbels was observed highest in F_3 (100kg N, 50kg P_2O_5

Table 29: Interactive effect of irrigation and spacing on harvest index (%) during 2004-05 and 2005-06

Treatment	Spacing (2004-05)			
	S_1 (30x30cm)	S_2 (45x30cm)	S_3 (60x30cm)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	13.36	12.41	11.06	12.28
I_2 (90mm)	13.04	12.25	11.05	12.11
I_3 (120mm)	8.13	7.23	6.88	7.41
Mean	11.51	10.63	9.66	

Treatment	Spacing (2005-06)			
	S_1 (30x30cm)	S_2 (45x30cm)	S_3 (60x30cm)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	15.39	14.43	13.04	14.29
I_2 (90mm)	15.11	14.40	13.23	14.25
I_3 (120mm)	12.62	11.81	12.12	12.19
Mean	14.38	13.55	12.80	

CD at 5%	Irrigation	Spacing	Irrigation x Spacing
2004-05	0.43	NS	0.55
2005-06	0.50	0.35	0.60

Table 30: Test weight (g) of carrot seed crop affected by various irrigation, fertility and spacing

Treatment	Main umbel		First order umbel		Second order umbel	
	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06
Irrigation levels (CPE)						
I_1 (60mm)	2.96	2.88	2.64	2.58	1.86	1.81
I_2 (90mm)	2.82	2.75	2.38	2.32	1.73	1.68
I_3 (120mm)	2.66	2.57	2.15	2.10	1.58	1.51
CD at 5%	0.07	0.04	0.03	0.03	0.02	0.02
Fertility levels (N:P:K kg/ha)						
F_1 (60:30:30)	2.76	2.69	2.33	2.28	1.68	1.63
F_2 (80:40:40)	2.83	2.74	2.38	2.33	1.72	1.67
F_3 (120:50:50)	2.85	2.77	2.45	2.40	1.75	1.71
CD at 5%	0.03	0.03	0.01	0.01	0.03	0.04
Spacing (cm)						
S_1 (30x30)	2.77	2.70	2.33	2.28	1.69	1.64
S_2 (45x30)	2.83	2.74	2.39	2.34	1.72	1.67
S_3 (60x30)	2.85	2.76	2.44	2.39	1.75	1.70
CD at 5%	0.03	0.03	0.01	0.01	0.03	0.04

and 50kg K_2O/ha) fertility level which was statistically at par with F_2 level of fertility in main and second order umbels. The minimum test weight in the three order umbels was found in F_1 (60kg N, 30kg P_2O_5 and 30kg K_2O per ha). Regarding spacing of S_3 (60 x 30cm) the widest spacing gave maximum test weight followed by S_2 (45 x 30cm). The minimum test weight of main, first and second order umbels seed was recorded in 30x30cm, the closest spacing. If we look at the test weight of various order umbels in Table 30, we find that main umbel seed shows higher test weight followed by first order umbel and the least test weight was found in second order umbel in all the irrigation, fertility and spacing treatments.

Data presented in Table 31 revealed that test weight of main, first and second order umbel seed was significantly affected by interaction of irrigation x fertility levels during both the years. The maximum test weight of each umbel order was recorded in most frequent irrigation treatment (I_1), fertilized with 100kg N, 50kg P_2O_5 and 50kg K_2O per ha i.e. F_3 fertility level, where as minimum test weight of the three order umbel in each season was observed in I_3 (120mm CPE) irrigation regime fertilized with 60kg N, 30kg P_2O_5 and 30kg K_2O per ha i.e. in F_1 treatment. The I_3F_2 treatment combination also gave statistically similar test weight to that of I_3F_1 in all the three types of umbels. The

Table 31: Interactive effect of irrigation and fertility on Test weight (g) during 2004-05 and 2005-06

Irrigation levels (CPE)	Main umbel fertility 2004-05				First order umbel fertility 2004-05				Second order umbel fertility 2004-05			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
I_1 (60mm)	2.90	2.95	3.03	2.96	2.53	2.61	2.77	2.64	1.78	1.87	1.93	1.86
I_2 (90mm)	2.74	2.86	2.87	2.82	2.34	2.39	2.40	2.38	1.71	1.75	1.73	1.73
I_3 (120mm)	2.63	2.67	2.67	2.66	2.12	2.14	2.18	2.15	1.56	1.54	1.58	1.56
Mean	2.76	2.83	2.85		2.33	2.38	2.45		1.68	1.72	1.75	
	2005-06				**2005-06**				**2005-06**			
I_1 (60mm)	2.82	2.87	2.94	2.88	2.48	2.56	2.71	2.58	1.73	1.82	1.90	1.82
I_2 (90mm)	2.67	2.77	2.79	2.75	2.29	2.33	2.35	2.32	1.66	1.70	1.68	1.68
I_3 (120mm)	2.56	2.57	2.57	2.57	2.06	2.09	2.13	2.10	1.51	1.50	1.53	1.51
Mean	2.69	2.74	2.77		2.28	2.33	2.40		1.63	1.67	1.71	

CD at 5%	Irrigation	Fertility	Irrigation x Fertility	Irrigation	Fertility	Irrigation x Fertility	Irrigation	Fertility	Irrigation x Fertility
2004-05	0.07	0.03	0.06	0.03	0.01	0.02	0.02	0.03	0.06
2005-06	0.04	0.03	0.05	0.03	0.01	0.02	0.02	0.04	0.06

interaction of irrigation and spacing on test weight of main umbel seed was also affected significantly in 2005-06 (Table 32 and 33). Maximum (2.93g) test weight was noticed with I_1S_3 treatment which was followed by and statistically at par with I_1S_2 treatment interaction. The minimum (2.57g) test weight was observed in I_3S_1, I_3S_2 and I_3S_3 treatments. Similarly, test weight of first order umbel seed was significantly higher (2.73g in 2004-05 and 2.67g in 2005-06) in I_1S_3 treatment combination over other treatment combinations.

4.1.2.2 Standard germination of main umbel, first order umbel and second order umbel seed

Germination percent of main umbel, first order umbel and second order umbel seed are presented in Table 34. Different irrigation treatments had significant effect on seed germination. Highest seed germination of three order umbels in both the seasons was recorded when crop was irrigated at 60mm CPE (I_1) followed by irrigation at 90mm CPE (I_2) and lowest seed germination was recorded at 120mm CPE (I_3). Various fertility levels also had significant effect on seed germination. Maximum seed germination during the two years of investigation was found when the crop was fertilized with 100kg N, 50kg P_2O_5 and 50kg K_2O per hectare i.e. in F_3 treatment of fertility which was followed by F_2 and the minimum seed germination of the three types of umbels

Table 32: Interactive effect of irrigation and spacing on Test weight (g) of main umbel seed during 2005-06

Treatment	Spacing (2005-06)			
	S_1 (30x30cm)	**S_2 (45x30cm)**	**S_3 (60x30cm)**	**Mean**
Irrigation levels (CPE)				
I_1 (60mm)	2.82	2.89	2.93	2.88
I_2 (90mm)	2.70	2.76	2.78	2.75
I_3 (120mm)	2.57	2.57	2.57	2.57
Mean	2.70	2.74	2.76	

CD at 5%	Irrigation	Spacing	Irrigation x Spacing
2005-06	0.04	0.03	0.05

Table 33: Interactive effect of irrigation and spacing on Test weight (g) of first order umbel seed during 2004-05 and 2005-06

Treatment	Spacing 2004-05			
	S_1 (30x30cm)	S_2 (45x30cm)	S_3 (60x30cm)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	2.53	2.65	2.73	2.64
I_2 (90mm)	2.34	2.37	2.41	2.38
I_3 (120mm)	2.11	2.15	2.18	2.15
Mean	2.33	2.40	2.44	

Treatment	Spacing (2005-06)			
	S_1 (30x30cm)	S_2 (45x30cm)	S_3 (60x30cm)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	2.48	2.60	2.67	2.58
I_2 (90mm)	2.29	2.32	2.36	2.32
I_3 (120mm)	2.06	2.11	2.13	2.10
Mean	2.28	2.34	2.39	

CD at 5%	Irrigation	Spacing	Irrigation x Spacing
2004-05	0.03	0.01	0.02
2005-06	0.03	0.01	0.02

Table 34: Effect of irrigation, fertility and spacing on standard germination percent in carrot

Treatment	Main umbel		First order umbel		Second order umbel	
	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06
Irrigation levels (CPE)						
I_1 (60mm)	85.51	84.67	83.51	82.51	74.14	72.16
I_2 (90mm)	82.93	81.93	81.52	80.49	67.77	65.72
I_3 (120mm)	81.82	80.82	79.97	78.97	61.93	59.98
CD at 5%	0.07	0.12	0.23	0.25	0.36	0.16
Fertility (N:P:K kg/hac)						
F_1 (60:30:30)	82.49	81.49	80.97	79.77	65.68	63.76
F_2 (80:40:40)	83.35	82.43	81.54	80.51	67.78	65.83
F_3 (100:50:50)	84.42	83.51	82.49	81.49	70.37	68.28
CD at 5%	0.38	0.41	0.42	0.41	0.36	0.36
Spacing (cm)						
S_1 (30x30)	82.92	81.98	81.22	80.18	67.10	65.15
S_2 (45x30)	83.41	82.41	81.60	80.60	68.03	65.93
S_3 (60x30)	83.92	83.04	82.18	81.18	68.70	66.78
CD at 5%	NS	NS	NS	NS	N.S	NS

during the two years of experimentation was observed in F_1 (60kg N, 30kg P_2O_5 and 30kg K_2O per ha) treatment. Various spacing treatments could not show any effect on the germination of carrot seed.

The interaction between irrigation and fertility was also found significant for standard germination in 2004-05 and 2005-06 in various order umbel seed (Table 35). The perusal of table reveals that highest seed germination percentage (86.53, 84.53 and 76.35% in main, first and second order umbel seed, respectively in 2004-05) was recorded where crop was irrigated at I_1 (60mm CPE) and fertilized with 100kg N, 50kg P_2O_5 and 50kg K_2O per ha. The minimum seed germination (80.00, 78.23 and 57.61% in main, first and second order umbel seed, respectively in 2005-06) was observed when the crop was irrigated at 120mm CPE (I_3) under F_1 (60kg N, 30kg P_2O_5 and 30kg K_2O per ha) fertility level. The table also shows that the germination of main umbel seed was observed maximum followed by first order umbel seed and the minimum germination was found in second order umbel seed.

4.1.2.3 Seed vigour index of main umbel, first order umbel and second order umbel seed

The data of seed vigour index of main umbel, first order umbel and second order umbel seed is presented in Table 36. The data reveals that all the three order umbel

Table 35: Interactive effect of irrigation and fertility on standard germination percent during 2004-05 and 2005-06

Irrigation levels (CPE)	Main umbel fertility 2004-05				First order umbel fertility 2004-05				Second order umbel fertility 2004-05			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
I_1 (60mm)	84.73	85.25	86.53	85.51	82.73	83.25	84.53	83.51	71.80	74.26	76.35	74.14
I_2 (90mm)	81.73	82.82	84.24	82.93	80.96	81.37	82.24	81.52	65.77	67.46	70.07	67.77
I_3 (120mm)	81.00	81.98	82.47	81.82	79.23	80.00	80.69	79.97	59.46	61.63	64.69	61.93
Mean	82.49	83.35	84.42		80.97	81.54	82.49		65.68	67.78	70.37	
	2005-06				**2005-06**				**2005-06**			
I_1 (60mm)	83.73	84.48	85.82	84.67	81.73	82.25	83.53	82.51	69.86	72.30	74.33	72.16
I_2 (90mm)	80.73	81.82	83.24	81.93	79.96	80.26	81.24	80.49	63.79	65.47	67.89	65.72
I_3 (120mm)	80.00	80.98	81.47	80.82	78.23	79.00	79.69	78.97	57.61	59.71	62.61	59.98
Mean	81.49	82.43	83.51		79.77	80.51	81.49		63.76	65.83	68.28	

CD at 5%	Irrigation	Fertility	Irrigation x Fertility	Irrigation	Fertility	Irrigation x Fertility	Irrigation	Fertility	Irrigation x Fertility
2004-05	0.07	0.38	0.66	0.23	0.42	0.72	0.36	0.36	0.62
2005-06	0.12	NS	0.70	0.28	0.41	0.71	0.16	0.36	0.62

Table 36: Seed vigor index of carrot seed as affected by various irrigation, fertility and spacing levels

Main umbel			First order umbel		Second order umbel	
Irrigation levels (CPE)	**2004-05**	**2005-06**	**2004-05**	**2005-06**	**2004-05**	**2005-06**
I_1 (60mm)	1444.81	1409.36	1355.95	1326.10	1161.05	1126.71
I_2 (90mm)	1385.96	1352.44	1304.31	1274.61	1117.70	1090.51
I_3 (120mm)	1319.74	1288.48	1241.70	1213.40	1037.42	1012.79
CD at 5%	20.08	19.09	15.49	17.55	12.11	22.39.
Fertility levels (N:P:K kg/ha)						
F_1 (60:30:30)	1364.19	1332.04	1277.10	1247.43	1087.70	1060.51
F_2 (80:40:40)	1385.45	1349.30	1307.31	1278.09	1107.18	1078.25
F_3 (100:50:50)	1400.87	1368.91	1317.55	1288.59	1121.29	1091.25
CD at 5%	18.36	16.39	13.86	16.05	13.23	18.28
Spacing (cm)						
S_1 (30x30)	1373.95	1335.28	1287.29	1259.26	1084.80	1072.32
S_2 (45x30)	1384.02	1348.83	1302.37	1272.26	1109.61	1073.02
S_3 (60x30)	1392.55	1366.14	1312.30	1282.59	1121.75	1084.68
CD at 5%	NS	16.39	13.86	16.05	13.23	18.28

seed gave highest (1444.81, 1355.95 and 1161.05 in main, first and second order umbel, respectively in 2004-05) vigour index in I_1 (60mm CPE) irrigation regime followed by I_2 (90mm CPE) level of irrigation. The minimum seed vigour index was found in I_3 irrigation treatment. Various fertility levels also influenced the vigour of seed significantly. Maximum vigour index of the three order umbel seed was observed in F_3 fertility level followed by F_2, while the minimum vigour of the seed was found in F_1 treatment. Like irrigation, fertility and spacing treatments too significantly affected the vigour index of seed in various order umbels. Maximum vigour of the seed was recorded under widest (S_3) spacing (60 x 30cm) followed S_2 spacing at 45 x 30cm. The minimum vigour index of seed was found in S_1 (30 x 30cm) treatment.

The irrigation x fertility and irrigation x spacing interaction was found significant for vigour index of various order umbel seed during two consecutive years of experimentation Table 37, 38 and 39. The irrigation x fertility interaction for 2004-05 and 2005-06 in main, first and second order umbels showed that I_1F_3 interaction gave highest seed vigour index, which was statistically at par with I_1F_2. The minimum seed vigour index (1271.93, 1228.17 and 1025.16 in main, first and second order umbel seed, respectively in 2004-05) was observed in I_3F_1 treatment interaction.

Table 37: Interactive effect of irrigation and fertility on vigour Index of main umbel and first order umbel during 2004-05 and 2005-06

Main umbel

Irrigation × Fertility
2005-06

Irrigation	F_1	F_2	F_3	Mean
I_1	1398.77	1402.62	1426.58	1409.33
I_2	1325.42	1354.14	1377.76	1352.44
I_3	1271.93	1291.14	1302.37	1288.48
Mean	1332.04	1349.30	1368.91	
CD at 5%	Irrigation	Fertility	Irrigation × Fertility	
2005-06	19.09	16.39	27.07	

first Order umbel

Irrigation × Fertility
2004-05

Irrigation	F_1	F_2	F_3	Mean
I_1	1325.18	1365.78	1376.89	1355.95
I_2	1277.95	1308.23	1326.76	1304.31
I_3	1228.17	1247.92	1249.01	1241.70
Mean	1277.10	1307.31	1317.55	
CD at 5%	Irrigation	Fertility	Irrigation × Fertility	
2004-05	15.49	13.86	18.68	

2005-06

Irrigation	F_1	F_2	F_3	Mean
I_1	1296.41	1335.67	1346.22	1326.10
I_2	1247.95	1277.23	1298.65	1274.61
I_3	1197.95	1221.36	1220.90	1213.40
Mean	1247.43	1278.09	1288.59	
CD at 5%	Irrigation	Fertility	Irrigation × Fertility	
2005-06	17.55	16.05	20.49	

Table 38: Interactive effect of irrigation and fertility on vigour index of second order umbel seed during 2004-05 and 2005-06

Treatment	Fertility levels (N:P:K kg/ha) (2004-05)			
	F_1 (60:30:30)	F_2 (80:40:40)	F_3 (100:50:50)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	1139.28	1161.42	1182.44	1161.05
I_2 (90mm)	1098.65	1119.27	1135.17	1117.70
I_3 (120mm)	1025.16	1040.86	1046.25	1037.42
Mean	1087.70	1107.18	1121.29	

Treatment	Fertility levels (N:P:K kg/ha) (2005-06)			
	F_1 (60:30:30)	F_2 (80:40:40)	F_3 (100:50:50)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	1104.61	1127.75	1147.77	1126.71
I_2 (90mm)	1070.09	1093.71	1107.73	1090.51
I_3 (120mm)	1006.83	1013.30	1018.25	1012.79
Mean	1060.51	1078.25	1091.25	

CD at 5%	Irrigation	Fertility	Irrigation x Fertility
2004-05	12.11	13.23	15.60
2005-06	22.39	18.28	28.33

Table 39: Interactive effect of irrigation and spacing on vigour index of second order umbel seed during 2004-05 and 2005-06

Treatment	Spacing (2004-05)			
	S_1 (30x30cm)	S_2 (45x30cm)	S_3 (60x30cm)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	1136.32	1165.44	1181.37	1161.05
I_2 (90mm)	1096.85	1123.93	1132.30	1117.70
I_3 (120mm)	1021.24	1039.46	1051.58	1037.42
Mean	1084.80	1109.61	1121.75	

Treatment	Spacing (2005-06)			
	S_1 (30x30cm)	S_2 (45x30cm)	S_3 (60x30cm)	Mean
Irrigation levels (CPE)				
I_1 (60mm)	1115.43	1124.55	1140.15	1126.71
I_2 (90mm)	1080.85	1090.93	1099.75	1090.51
I_3 (120mm)	1020.69	1003.57	1014.13	1012.79
Mean	1072.32	1073.02	1084.68	

CD at 5%	Irrigation	Spacing	Irrigation x Spacing
2004-05	12.11	13.23	15.60
2005-06	22.39	18.28	28.33

Regarding irrigation x spacing, the interaction was found significant only for second order umbel seed (Table 39). The data presented in the table manifested that the maximum (1181.37 and 1140.15 during 2004-05 and 2005-06 respectively) seed vigour index for second order umbel seed was recorded in stecklings planted at 60 x 30cm spacing and when irrigated at 60mm CPE (I_1S_3) which was followed by I_1S_2. The minimum vigour index in second order umbel seed was observed in I_3S_1 treatment combination during 2004-05 and in I_3S_2 in 2005-06.

4.1.3 Moisture studies

4.1.3.1 Consumptive use of water

The values of consumptive use of water is presented in Table 40 for various irrigation levels tried.

A close perusal of the data indicate that the consumptive use of water was highest 48.15cm in 2004-05 and 41.79cm in 2005-06 under wettest irrigation regime i.e. in I_1 followed I_2. The minimum (37.47cm in first and 31.74cm in second year) consumptive use was recorded under I_3 (120mm CPE), the direst irrigation regime.

4.1.3.2 Water use efficiency (WUE)

The values of water use efficiency calculated under various irrigation levels are given in Table 40. Data revealed that during 2004-05 highest water use efficiency (25.92 kg/ha/cm) was recorded under I_2 irrigation treatment followed

Table 40: Consumptive use of water and water use efficiency (WUE) of carrot seed crop under various irrigation levels

Year	Treatment	Consumptive use of water (cm)	Seed yield (kg/ha)	Water use efficiency (kg/ha/cm)
2004-05	I_1 (60 mm CPE)	48.15	1122	23.30
	I_2 (90 mm CPE)	40.04	1038	25.92
	I_3 (120 mm CPE)	37.47	819	21.86
2005-06	I_1 (60 mm CPE)	41.79	1006	24.07
	I_2 (90 mm CPE)	36.85	958	26.00
	I_3 (120 mm CPE)	31.74	793	24.98

by I_1 (23.30kg/ha/cm) and lowest in I_3 (21.86kg/ha/cm) treatment. During 2005-06 too the I_2 (irrigation at 90mm CPE) moisture regime again gave highest (26.00 kg/ha/cm) W.U.E. The W.U.E. of I_3 and I_1 irrigation treatment in 2005-06 were very close to each other.

4.1.1.13 Economics of carrot seed crop

Economics of carrot seed crop as affected by various irrigation, fertility and spacing levels are presented in Table 41.

Highest net return (Rs. 76375 per ha) was recorded in treatment $I_1F_3S_1$ treatment while lowest (Rs. 22470 per ha) was recorded in $I_3F_1S_3$ during 2004-05.

Like 2004-2005, in 2005-06 too maximum net return Rs. 73515 per ha was obtained in $I_1F_3S_1$ treatment combination and lowest (Rs. 22824) was found in $I_3F_1S_3$ treatment combination.

Table 41: Economics of carrot seed crop as affected by various irrigation, fertility and spacing levels

Treatment	2004-05				2005-06			
	Seed yield (q/ha)	Gross income (Rs.)	Cost of cultivation (Rs.)	Net profit (Rs.)	Seed yield (q/ha)	Gross income (Rs.)	Cost of cultivation (Rs.)	Net profit (Rs.)
$I_1F_1S_1$	12.77	102160	29350	72810	12.48	99840	30850	68990
$I_1F_1S_2$	10.83	86640	28550	58090	9.18	73440	30050	43390
$I_1F_1S_3$	8.15	65200	27750	37450	7.43	59440	29250	30190
$I_1F_2S_1$	12.98	103840	29612	74228	12.82	102560	31112	71448
$I_1F_2S_2$	11.55	92400	28812	63588	9.6	76800	30312	46488
$I_1F_2S_3$	8.67	69360	28012	41348	7.69	61520	29512	32008
$I_1F_3S_1$	13.28	106240	29865	76375	13.11	104880	31365	73515
$I_1F_3S_2$	12.11	96880	29065	67815	10.33	82640	30565	52075
$I_1F_3S_3$	9.12	72960	28265	44695	7.99	63920	29765	34155
$I_2F_1S_1$	11.78	94240	27350	68890	11.77	94160	28550	65610
$I_2F_1S_2$	9.80	78400	26550	51850	8.87	70960	27750	43210
$I_2F_1S_3$	7.28	58240	25760	32490	7.41	59280	26950	32330
$I_2F_2S_1$	12.75	102000	27612	74388	12.48	99840	28812	71028
$I_2F_2S_2$	10.62	84960	26812	58148	8.93	71440	2012	43428
$I_2F_2S_3$	7.94	63520	26012	37508	7.48	59840	27212	32628
$I_2F_3S_1$	12.85	102800	27865	74935	12.63	101040	29065	71975
$I_2F_3S_2$	11.19	89520	27065	62455	9.09	72720	28265	44455
$I_2F_3S_3$	8.76	70080	26265	43815	7.57	60560	27465	33095
$I_3F_1S_1$	8.75	70000	25850	44150	9.73	77840	26856	50984
$I_3F_1S_2$	7.04	56320	25050	31270	7.63	61040	26056	34984
$I_3F_1S_3$	5.84	46720	24250	22470	6.01	48080	25256	22824
$I_3F_2S_1$	9.84	78720	26112	52608	10.92	87360	27112	60248
$I_3F_2S_2$	7.85	62800	25312	37488	7.85	62800	26312	36488
$I_3F_2S_3$	6.32	50560	24512	26048	6.17	49360	25512	23848
$I_3F_3S_1$	10.41	83280	26365	56915	11.33	90640	27365	63275
$I_3F_3S_2$	8.27	66160	25565	40595	7.89	63120	26565	36555
$I_3F_3S_3$	7.05	56400	24765	31635	6.36	50880	25765	25115

CHAPTER - V

Discussion

The yield is the result of interaction between genetic potential and the environmental condition to which the plant is exposed during its life cycle. The yield potential of a genotype may be exploited only under the most optimum environmental conditions. Though, it is not possible to control precisely the environment under field conditions, yet favourable environment can be provided by judicious organization of manageable factors like water management, plant density and optimum plant nutrients (fertilizers) which to a considerable extent may help to harness the genetic potential of a cultivar.

The present investigation "Studies on Irrigation, fertility and spacing levels on carrot seed crop (*Daucus carota* L.)" was carried out at Vegetable Research Farm, CCS Haryana Agricultural University, Hisar. The results presented in the previous chapter are discussed here. In the present studies, the average seed yield and yield attributing characters of carrot seed crop were better during the first year of experimentation than in second year. The difference

during the two seasons of the experimentation within the same treatment were probably due to more favourable weather condition during first year. In 2004-05 sufficient rainfall was received during grand growth period, resulted in better growth of the crop which is evident from higher plant height, more number of branches per plant, number of umbels per plant and consequently the better yield.

5.1 Experiment

5.1.1 Effect of irrigation

Plant height, number of branches per plant and number of umbels per plant increased significantly with the increase in irrigation intensity during both the years. The pronounced effects of irrigation level on growth characters might be attributed due to beneficial effect of water on cell turgidity, cell elongation, photosynthesis, respiration, uptake of nutrients and translocation of photosynthates to the active growing plant parts. These observations are also supported by the results of Shain and Calovkina (1982), Batra (1985), Yadav (1995) and Nain (2003).

Seed yield per plant and per hectare and biological yield per hectare were influenced by the different irrigation treatments. Yield and yield attributing characters were better when the crop was irrigated at 60mm CPE (I_1). Among these characters, yield per hectare was at par or at par when crop was irrigated at 90mm CPE (I_2). The favourable effect of

irrigation may be explained on the basis of more plant height (Table 4) which ultimately led to more number of branches and hence more number of umbels per plant.

Significant increase in seed yield under increased irrigation levels corroborate the finding of Patel *et al.* (1988), Sharma and Prasad (1990) in fennel; Marouelli *et al.* (1990) and Batra (1985) in carrot, Pareek and Sethi (1985) and Nain (2003) in coriander. However Howthorn (1952) reported that seed yield of carrot increased with medium and low soil moisture.

Harvest index is highly correlated with seed yield and was found to be maximum with the most frequent irrigation treatment (I_1). Higher harvesting index in I_1 irrigation level indicated proportionally more increase in seed yield and straw yield. It may be due to higher translocation of photosynthates from source to sink. Quality of seed is also determined by its boldness expressed in term of test weight. Test weight and germination percent was found maximum when crop was irrigated at 60mm CPE (I_1).

These results are in agreement with the finding of Marouelli *et al.* (1990) and Batra (1985) in carrot who reported higher test weight with frequent irrigations.

Consumptive use of water by carrot seed crop increased with increase in irrigation frequency. This may be due to the fact that soil layer remained wetter for the longer

period under frequent irrigation treatments, which resulted in higher rate of evaporation as compared to I_3 irrigation treatment. High rate of water absorption by roots in frequently irrigated plots, maintained high leaf water potential, better stomal conductance and there by higher transpiration. This might also be due to better vigour and large exposure of plant canopy which resulted in utilization of available soil moisture more efficiently and ultimately increased in consumption of water. The results are in conformity with the findings of Batra and Kalloo(1991) in carrot, Yadav (1995) in fennel and Nain (2003) in coriander seed production.

Water use efficiency was higher when irrigation water was applied at 90mm CPE (I_2) as compared to irrigating the crop at 60mm CPE (I_1) and 120mm CPE (I_3) in both the seasons.

Effect of fertility

There are several factors which are responsible for quality seed production of carrot. Among these, the use of proper dose of fertilizer is one of the most important factor which influence both quantitative and qualitative yielding capacity of carrot seed crop.

The seed yield and the yield contributing characters of carrot seed crop were better when F_2 (80kg N, 40kg P_2O_5 of 40kg K_2O) dose was applied which was statistically at par with F_3 (100kg N, 50kg P_2O_5 and 50kg

K_2O/ha) dose (Table 21). Nitrogen, phosphorus and potash are essential nutrients for crop growth as well as for seed formation and have been reported to exert a great influence on the seed yield and considered a key factor in carrot seed production. The height of plants was appreciably favoured by high fertility (F_3) treatments followed by F_2. Plant height has been reported to increase with the application of nitrogen reported by Howthorn (1952), Malik and Kanwar (1969), Ahmed and Tanki (1989) in carrot.

The yield increase was due to its favourable effect of nutrients on growth and yield attributes like plant height, number of first and second order umbels per plant and seed yield contributed by individual umbel. Seed yield is directly dependent upon the performance of yield attributes and a perusal of data pertaining to growth and yield attributes revealed that the application of F_2 (80kg N, 40kg P_2O_5 and 40kg K_2O) dose of fertility was sufficient for carrot seed production. Kumar and Nandpuri (1978), Sharma and Singh (1981) and Ahmed and Tanki (1989) have also reported that 75 to 100 kg N/ha was sufficient for carrot seed production.

Highest and significantly superior number of first and second order umbels were recorded with F_3 fertility treatment closely followed by F_2. Similar results have also been obtained by Kumar and Nandpuri (1978), Sharma and Singh (1981) and Ahmed and Tanki (1989). They reported

that the number of umbels increased with the increase in fertility levels.

Higher seed yield of main umbel, first order and second order umbel with F_3 treatment may be due to its beneficial effect on plant growth. Singh *et al.* (1994) have also reported that higher dose of fertility increased the plant height, umbels/plant and seed yield per plant.

The significant increase in seed yield (q/ha) with the increasing doses of fertility may be explained on the basis of better plant growth, increase in first and second order umbels and increase in test weight of main, first order and second order umbel seed with every increase in fertility level. There was increase in seed yield (q/ha) at F_2 and F_3 treatments, however, the differences were not significant. This may be due to the non-significant differences in the test weight of seed obtained from main and second order umbels under F_2 and F_3 treatments This might be attributed to the incapability of plant in translocating the additional food material available as a result of application of F_3 from source to sink (seed).

Highest seed germination percentage of main, first and second order umbel was recorded with F_3 which was significantly superior over other doses of fertility. Main umbel seed gave highest germination percentage followed by first and second order umbels. Increase in germination with

higher fertility levels had also been reported by Krarup *et al.* (1976) and Gray *et al.* (1983).

An important attribute of seed quality i.e. seed vigour which improved significantly (in each order umbel) by each fertility level. These results are in concurrence with the finding of Singh *et al.* (1994) who have reported higher seed vigour with application of fertilizer.

Effect of plant spacing

The spacing of stecklings (plant density) has been reported to have a tremendous influence on seed yield per unit area. Closer spacing between plants increased the plant density per unit area and is one of the best means of increasing seed yield. In the present study also plant density per unit area influenced the seed yield considerably. Among the three spacings tried, the closest spacing 30 x 30cm gave significantly higher seed yield per hectare in comparison to other spacings during both the years. Saini and Rastogi (1976), Kumar and Nandpuri (1978), Sharma and Singh (1981), Malik *et al.* (1983), Lal and Pandey (1986) have also reported consistent findings and the results of the study under discussion are in agreement with their results. Although the widest spacing 60 x 30cm resulted in maximum seed yield per plant (Table 17), however, seed yield per unit area was significantly lower in comparison to closer spacing. It might be as a result of better conditions for growth but minimum seed yield per hectare recorded at widest spacing

suggested that higher seed yield per plant was not sufficient enough to compensate the loss in seed yield per hectare due to decreased number of plants per unit area. By reducing inter row spacing to some extent for a given plant population reduced intra-species competition, competitive and cooperative interaction and resulted in higher yield.

In this study, higher number of branches, umbels and seed yield per plant under wider spacing can be attributed to plenty of space, air, light and nutrients available to the plants in comparison to closer spacing. The results are in concurrence with those obtained by Krarup and Montealegre (1976), Kumar and Nandpuri (1978), Singh *et al.* (1994), Muhammad and Anjum (2001) in carrot, whereas Sharma and Lal (1991), Saharan and Baswana (1991) in radish, Nehra *et al.* (1998), Malav and Yadav (1997) in coriander, Yadav and Khurana (2000) in fennel.

The interaction effect between spacing and irrigation revealed that combination of widest spacing 60 x 30cm with maximum number of irrigation at 60 mm CPE produced maximum seed yield per plant, however, per hectare seed yield was maximum under closer spacing (30 x 30cm) with maximum number of irrigation i.e. in I_1 (60mm CPE) treatment.

The quality of seed as determined by its boldness (test weight), germination percent and seed vigour was also influenced by various treatments. Widest spacing 60 x 30cm

significantly increased the test weight of seed harvested from main, first order and second order umbels as compared to closest spacing of 30 x 30cm. The seed vigour also behaved in the same fashion and was recorded highest under widest spacing of 60 x 30cm. These results are similar to the findings of Gill *et al.* (1981), Singh and Malik (1986), Singh *et al.* (1994) and Muhammad and Anjum (2001) who reported that seed produced under wider spacing had higher test weight and seed vigour as compared to closer spacing. This might be due to better conditions of growth under wider spacing resulting in bold size seeds having better vigour as compared to closer spacing.

Interaction effect

Significant differences were observed in relation to interaction between irrigation x fertility, irrigation x spacing and fertility x spacing for seed yield and biological yield. Seed yield as well as biological yield were higher by maintaining the steckling spacing at 30 x 30cm, fertilized with 100kg N, 50kg P_2O_5 and 50kg K_2O per hectare (F_3) and by applying irrigation at 60mm CPE (I_1).

Economics of different treatment combinations was also calculated and the results indicated that maximum net profit was obtained when the stecklings of the carrot were planted at a distance of 30 x 30cm, fertilized with 100kg N, 50kg P_2O_5 and 50kg K_2O per hectare (F_3) and by irrigating the crop at 60mm CPE (I_1).

CHAPTER - VI

Summary and Conclusion

The present investigation "Studies on irrigation, fertility and spacing levels on carrot seed crop (*Daucus carota* L.)" was conducted during two consecutive winter seasons of 2004-05 and 2005-06 in sandy loam soil at Vegetable Research Farm and Laboratories of Department of Vegetable Science and Department of Seed Science and Technology, CCS Haryana Agricultural University, Hisar. The summary of the results is given below.

6.1 Effect of irrigation

6.1.1 Maximum plant height was recorded when the crop was irrigated at 60mm CPE (I_1) during both the years. The plant attained minimum height when crop was irrigated at 120mm CPE (I_3).

6.1.2 Number of branches, first order umbels and second order umbels per plant were significantly higher in I_1 (60mm CPE) treatment, followed by I_2 (90mm CPE) and minimum in I_3 (120mm CPE).

6.1.3 Seed yield of main umbel, first order umbels and second order umbels per plant was recorded

maximum with highest number of irrigations (60mm CPE) during both the years.

6.1.4 Seed yield per plant, per hectare and biological yield increased significantly with increase in irrigation frequency and was significantly higher in I_1 (60mm CPE) treatment over the rest of irrigation treatments.

6.1.5 Test weight, germination (%) and seed vigour index were also higher under maximum irrigation frequency (60mm CPE) in main, first order and in second order umbel seed during both the seasons.

6.1.6 Consumptive use of water was observed maximum under wettest irrigation regime (I_1) followed by I_2 and I_3 during both seasons.

6.1.7 Water use efficiency (WUE) was observed maximum in I_2 irrigation treatment followed by I_1 and least in I_3 in 2004-05. However in 2005-06 W.U.E. was found maximum in I_2 and minimum was recorded in I_1.

6.2 Effect of fertility

6.2.1 Application of F3 (100kg N, 50kg P_2O_5 and 50kg K_2O/ha) fertility dose per hectare significantly improved plant height and number of branches per plant in comparison to other fertility levels.

6.2.2 Maximum number of first order umbels and second order umbels per plant was recorded with highest fertility dose in both seasons.

6.2.3 Seed yield of main umbel, first order umbels and second order umbels per plant were also significantly higher with highest fertility dose (100kg N, 50kg P_2O_5 and 50kg K_2O per ha) in both the growing seasons of experimentation.

6.2.4 Seed yield per plant, per hectare and biological yield increased with increase in fertility levels during both the years and highest was recorded with F_3 (100kg N, 50kg P_2O_5 and 50kg K_2O/ha fertility level.

6.2.5 Test weight, germination (%) and seed vigour index of main umbel, first order umbel and second order umbel were also higher under highest fertility levels i.e. F_3 (100kg N, 50kg P_2O_5 and 50kg K_2O per ha).

6.3 Effect of spacing

6.3.1 Plant height showed non-significant difference among the three spacing treatments. However, number of branches and umbels per plant were significantly higher under wider spacing.

6.3.2 Widest (60 x 30cm) plant spacing increased the seed yield per plant significantly in comparison to closer spacing, whereas, highest seed yield per hectare was obtained under closest spacing (30 x 30cm) during both the years of investigation.

6.3.3 Test weight and seed vigour were also higher under wider spacing (60 x 30cm) and found significantly

superior than 30 x 30cm spacing. However, germination percent was statistically par in all the spacing treatments.

CONCLUSION

From the present investigation, it can be concluded that for raising a successful seed crop of carrot cv. Hisar Gairic at Hisar (Haryana), stecklings may be planted at 30 x 30cm spacing, applying with 100kg N 50 kg P_2O_5 and 50 kg K_2O per ha. and irrigating the crop at 60mm CPE. Highest net return (Rs. 76375/ha in 2004-05 and Rs. 73515/ha in 2005-06) was found with above treatment.

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ABSTRACT

a.	Title of thesis	:	**Studies on Irrigation, fertility and spacing levels on carrot seed crop" (*Daucus carota* L.)**
b.	Full name of degree holder	:	**Vikash Hooda**
c.	Title of degree	:	DOCTOR OF PHILOSOPHY
d.	Name and Address of Major Advisor	:	**DR. A.C. YADAV** Professor, Department of Vegetable Science CCS Haryana Agricultural University, Hisar – 125004, India
e.	Degree awarding University/Institute	:	CCS Haryana Agricultural University, Hisar-125004 (Haryana) INDIA
f.	Year of award of degree	:	2006
g.	Major subject	:	Vegetable Science
h.	Total number of pages in the thesis	:	102+xi
i.	Number of words in the abstract	:	300 Approx.
j.	Key words	:	*Irrigation, fertility, spacing effect on seed yield of carrot*

The present investigation was conducted at the Vegetable Research Farm and Laboratories of the Department of Vegetable Science of the CCS Haryana Agricultural University, Hisar, over a period of two years (2004-05 and 2005-06). There were twenty-seven treatment combinations comprising of three irrigation levels (60mm, 90mm and 120mm CPE), three fertility levels (60:30:30, 80:40:40 and 100:50:50 N:P:K kg/ha) and three plant spacings (30 x 30, 30 x 45 and 30 x 60cm) which were laid out in split-split plot design with three replication.

Irrigating the crop at 60mm, CPE produced maximum plant height, number of branches per plant, first order umbels and second order umbels per plant. Highest seed yield per plant and per hectare, maximum germination percentage, test weight and seed vigour index was recorded with irrigating the carrot seed crop at 60mm CPE in

comparison to irrigation at 90mm and 120mm CPE during both years of investigation.

Carrot seed crop supplied with F3 fertility dose (100:50:50 NPK kg/ha) produced maximum plant height, number of branches, first order umbels and second order umbels per plant. Highest seed yield per plant and per hectare with better seed quality like highest test weight, germination percentage was obtained when 100kg N, 50kg P_2O_5 and 50kg K_2O was applied in comparison to other two fertility levels (80:40:40 and 60:30:30 N:P:K kg/ha) during both years of experimentation.

Regarding spacing plant height was observed maximum under closest spacing (30 x 30 cm) and minimum under widest spacing (30 x 60 cm). However, number of branches and umbels per plant were significantly higher under wider spacing. Widest plant spacing 30 x 60 cm increased the seed yield per plant significantly in comparison to closer spacing, whereas, highest seed yield per hectare was obtained under closest spacing of 30 x 30 cm during both the years of investigation.

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