

**EFFECT OF NUTRIENTS AND SPACINGS ON  
GROWTH, YIELD AND ESSENTIAL OIL  
CONTENT IN FENNEL (*Foeniculum vulgare* Mill.)**

By  
**AMEEN AHMED**

**DIVISION OF HORTICULTURE  
UNIVERSITY OF AGRICULTURAL SCIENCES  
BANGALORE  
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CONTENT IN FENNEL (*Foeniculum vulgare* Mill.)**

By  
**AMEEN AHMED**

Thesis submitted to the  
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in partial fulfilment of the requirements  
for the award of the degree of

**Master of Science (Horticulture)**

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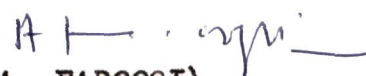
*Dedicated to*  
*My Beloved Parents*  
**P. Hameedur Rahaman**  
**and**  
**Kulsum Bi**

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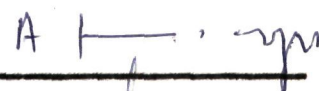
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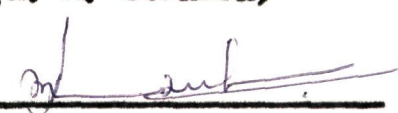
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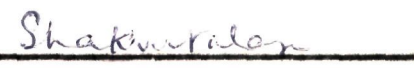
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# **INTRODUCTION**

## I INTRODUCTION

Fennel, commonly known as Saunf or Badi Saunf, belongs to family Umbelliferae and genus Foeniculum. It is a stout, glabrous, aromatic herb, 5-6 feet high, leaves pinnately decomposed; flowers small, yellow and in compound terminal umbels; fruits oblong, ellipsoid or cylindrical, 6-7 mm in length, straight or slightly curved, greenish or yellowish brown, mericarp 5 ridged with prominent vittae (Anon., 1956).

The plants belonging to the genus Foeniculum are of annual, biennial or perennial herbs - distributed in South Europe and the Mediterranean region. Foeniculum vulgare Mill. is widely cultivated throughout the temperate and sub-tropical regions of the world for its aromatic fruits and have been used as culinary spice by the Chinese, Indians and Egyptians since time immemorial (Anon., 1956 and Yelappan, 1977).

Fennel is a native of Southern Europe and Asia. A large number of varieties and races differing in size, odour and taste of the fruits, exist among wild and cultivated fennels. They are hardly distinguishable from one another and are regarded as races, varieties or sub-species of Foeniculum vulgare. The varieties which yield commercially important volatile oils are

generally referred to sub-species *capillaceum* and placed under two distinct varieties, var. *vulgare* (Mill.) - Thellung (cultivated or wild growing, yields bitter fennel oil) and var. *dulce* (Mill.) Thellung (cultivated and yielding sweet or Roman or Florence fennel oil). The variety *vulgare* is cultivated chiefly in Russia, Rumania, Hungary, Germany, France, Italy, India, Japan, Argentina and U.S.A. The cultivation of var. *dulce* is confined to France, Italy and Greece (Macedonia) in Southern Europe. However, Indian fennel is sometimes regarded as a distinct variety *Fanmorium* (Anon., 1956).

Fennel is cultivated mostly as a garden or home yard crop throughout India at all altitudes upto 2,000 metres and the area under fennel is fluctuating from year to year. It requires a fairly mild climate and is cultivated as a cold weather crop in the parts of Northern India. It does not succeed so well in South India except at high elevation (Anon., 1956).

Important fennel growing states in India are Gujarat and Rajasthan. Kaira, Baroda and Ahmedabad in Gujarat and Kota, Jaipur, Ajmer and Udaipur in Rajasthan are the important districts of fennel cultivation. Besides these places, on a small scale it is also grown in some parts of Maharashtra, Uttar Pradesh, Madhya Pradesh, Punjab, Bihar, Karnataka and in Jammu and Kashmir (Velappan, 1977).

Fennel contributes substantially to the foreign exchange earnings of our country. During 1983-84, India produced about 30,000 tonnes of fennel seeds and exported 1552 tonnes and earned a foreign exchange of Rs.218.83 lakhs (Anon., 1984b).

The plant is pleasantly aromatic and is used as a pot herb. The leaves are used in fish sauce and garnishing. Leaf stalks are used in salad (Velappan, 1977). Fennel fruits contain a volatile oil. Volatile oil content of Indian fennel is only 0.7 to 1.2 per cent, whereas East European fennel contains 4-6 per cent volatile oil (Velappan, 1977). The oil is obtained by steam distillation of crushed fruits. It is a colourless or pale yellow liquid with a characteristic taste and odour. The main constituents of fennel oil is anethole (50-60%) and the other constituents are d-*L*- Fenchone, methyl chavicol, d-*L*-pinene, camphene, d-*L*-phellandrene, dipentane and foeniculin (P-anol prenyl ether). Basic constituents anisaldehyde and anisic acid are also reported to be present. Indian fennel oil contains over 70 per cent anethole and 6 per cent fenchone. It possesses a sweet taste (Guenther, 1950 and Rao, 1925).

Fennel oil is largely used as a flavouring agent in culinary preparations, confectionery, cordials and liquors. It is also used in cosmetics and as an important ingredient in medicinal preparations for infantile colic and flatulence. The vermifugal properties of the oil are

well known (Anon., 1956). The residue left over after distillation of fennel oil from the fruits is used as cattle feed. It contains 14-22 per cent proteins and 12-18.5 per cent fat (Guenther, 1950).

Dried fruits of fennel have fragrant odour and a pleasant aromatic taste. They are used for flavouring soups, meat dishes and sauces, bread rolls, pastries and confectionery. They are also used for flavouring liquors and in the manufacture of pickles. The fruits are included in the official pharmacopoeias of all countries and are considered useful in diseases of the chest, spleen and kidney and are used in several pharmaceutical preparations. A hot infusion of the fruits is used in indigenous medicine to increase lacteal secretions and to stimulate sweating (Anon., 1956).

Thickened leaf stalks of florence fennel are blanched and used as vegetable. The leaves are reported to have diuretic properties. The roots are regarded as purgative; they have an aromatic odour and taste.

In spite of a number of its household, industrial and medicinal uses in addition to the foreign exchange earnings by this crop, it is not being exploited commercially in our State. Since there is practically no information available locally on the production technology on this crop, it is not

perhaps popular among the cultivators. Hence, in order to develop the production technology and to popularise this important crop among the local farmers, the present studies were carried out, with the following objectives:

1. to study the main effects of nitrogen, phosphorus and spacings on growth and yield of fennel,
  2. to study the different interaction effects on the growth and yield of fennel,
  3. to find out the best combination of these factors to obtain the maximum seed and oil yield in fennel,  
and
  4. to study the performance of fennel crop under Bangalore condition.
-

## **REVIEW OF LITERATURE**

## II REVIEW OF LITERATURE

Any interruption in plant nutrition even for a short period has a negative effect on the yield which cannot be corrected by the supply of nutrients. To attain the maximum yield, there is a need to adjust the nutrient supply as required by the plants during the various stages of growth (Mengal, 1969).

As compared to other crops very little work has been carried out on the agronomic aspects of essential oil yielding crops and more so in fennel. Hence, literature pertaining to the agronomic aspects (nutrition and spacing) of fennel and other related umbelliferous crops is reviewed here under.

### 2.1 Agronomic studies on fennel

#### 2.1.1 Effect of nitrogen and phosphorus on growth, yield and essential oil content in fennel

As early as 1942, the cultivation and manuring of some umbelliferous crops including fennel (Foeniculum vulgare Mill.) have been studied by Boshart and reported that fennel gave a decrease in yield with small nitrogen application.

Stenzel (1958) discussed the practical points for cultivation of fennel as gleaned from the actual growers, culture and fertilization practices.

Velappan (1977) observed that fertilizer recommendation for fennel varied from state to state. In Madhya Pradesh, 40 kg N and 30 kg P<sub>2</sub>O<sub>5</sub> per hectare are being applied. In Gujarat, fertilizer dose recommended for P<sub>F</sub>-35 fennel was 100 kg N and 60 kg P<sub>2</sub>O<sub>5</sub> per hectare. Out of this, 40 kg N and whole of P<sub>2</sub>O<sub>5</sub> were applied as basal dose, 30 kg N, four weeks after transplanting and the remaining 30 kg N at the time of flowering. Band placement of fertilizers was found to be most beneficial.

Higher rates of nitrogen application produced more umbels per plant, increased the seed yield, oil yield and oil percentage in case of fennel (Abdullah et al., 1978).

Paliwal and Singh (1979) reported the response of fennel to increasing levels of N from 0 to 90 kg/ha and P from 0 to 60 kg/ha. There was a significant increase in yield from 607 to 1675 kg/ha from increasing N and 1095 to 1314 kg/ha from increasing P.

Randhawa et al. (1978) while studying the effect of nitrogen levels and sowing dates observed a significant influence of nitrogen on the seed yield. It was found

increased with each successive increase in the level upto 75 kg N/ha over the yield from control. The crop sown on 21st October gave the highest yield of seeds. The oil content in the seeds was not affected by the sowing dates and nitrogen levels.

In a fertilizer trial under the All India Coordinated Spices and Cashewnut Improvement Project at Jobner, a positive response to N was noticed for characters like plant height, branches per plant and <sup>seed</sup> yield. The seed yield was highest (18.54 q/ha) at 45 kg N/ha as compared to control (13.64 q/ha). However, phosphorus, Zn and B did not show any significant response to any of the characters studied (Anon., 1980).

Randhawa et al. (1981) in their three year nutritional trial reported the significant response of nitrogen upto 100 kg/ha, where the seed yield rose from 5.08 to 8.51 q/ha. They also reported the significant effect of phosphorus upto 40 kg/ha which resulted in the seed yield of 8.44 q/ha against 6.73 q/ha in control, showing thereby, a need to try still higher levels of phosphorus.

In another study, Randhawa and Gill (1982) found that the application of 30 kg N/ha produced the maximum seed yield (8.58 q/ha) compared to control (5.65 q/ha). According to them, an increase in seed yield with the application of nitroge could be due to its favourable effects on the yield attributing characters like number of branches (22.79) per plant and height of plant (97.35 cm).

Afridi et al. (1983) used N,  $P_2O_5$  and/or  $K_2O$  each at 60 or 90 kg/ha. The plants receiving N:P:K at 90:60:90 kg/ha grew best. However, the maximum yield (19.9 q/ha) was obtained in plots receiving the highest NPK dose.

At Jagudan, in a four year trial under the All India Co-ordinated Spices and Cashewnut Improvement Project (1980-83) the yield difference due to various treatments was found to be highly significant. The results showed that the treatment combination  $N_{45}+P_{30}+Zn+B$  gave the highest yield of 928.5 kg of seeds per hectare which was 68.5% more than control (Anon., 1983a).

Bhati et al. (1984) recommended the application of 60 kg N and 40 kg  $P_2O_5$  per hectare for fennel under Rajasthan condition. Out of this, 30 kg N and whole of  $P_2O_5$  were applied as basal dose and the remaining 30 kg N just before flowering.

### 2.1.2 Effect of different spacings on growth, yield and essential oil content in fennel

In North India, fennel seeds are sown either by broadcasting or in rows placed at 30-45 cm apart (Joshi, 1961).

El-Hamidi and Ahmed (1966) observed a positive correlation in the oil content in the plants grown under different spacings in fennel.

Lal and Sen (1971) examined nine samples of oil from different types of seeds of Indian varieties of Foeniculum vulgare and concluded that the maximum yield of oil could be obtained from very small seed types. However it was not known whether the smallness of the seeds was due to immaturity or the variety.

Velappan (1977) reported that the seeds were sown in rows at 45 to 60 cm apart and when the seedlings were of about four to five weeks old, they were thinned to 30 cm distance within the row. A row spacing of 60 cm<sup>on</sup>/heavy soils and 40-45 cm on light soils were reported to give higher yields.

El-Gengaihi and Abdulla (1978) tried ridge spacing of 20, 30 or 40 cm in fennel. They observed that the widest spacing produced the tallest plants and the greater number of umbels per plant. The seed yield was also highest at the widest spacing but the 30 cm spacing produced the highest seed yield and oil yield per hectare.

Randhawa and Gill (1982) observed that the plants sown in rows 45 cm apart gave the highest seed yield (8.46 q/ha) which was significantly superior to 30, 60, 75 and 90 cm row spacings. However, the final plant height, number of branches per plant and oil content were not affected significantly by different row spacings.

In Andhra Pradesh for the fennel selection, Lam Sel-II which is of 170 days duration and has a yield potential of 9.5 q/ha, one and half month old seedlings are transplanted at 2'x2' spacing in August. A seed rate of 3-4 kg/ha and 8-9 kg/ha is required for transplanting and direct sowing with seed drill, respectively has been recommended. In direct sowing the seedlings are later on thinned to required density (Anon., 1984a).

Under Rajasthan condition, the recommended spacing for transplanting the fennel is either 80x60 or 100x60 cm to obtain higher yields. In Chilli growing areas the fennel is grown as a mixed or intercrop with chilli (Bhati et al., 1984).

## 2.2 Agronomic studies on other related crops

### 2.2.1 Effect of different levels of nutrients on growth, yield and essential oil content in other related umbelliferous crops

Boshart (1942) reported the cultivation and manuring of some umbelliferous crops like caraway (Carum carvi), coriander (Coriandrum sativum), aniseed (Pimpinella anisum) and fennel (Foeniculum vulgare). He found that the yield of caraway increased with N application (40 kg N/ha in the first year and 70-80 kg N/ha in the second year). The P<sub>2</sub>O<sub>5</sub> requirement was not large and K<sub>2</sub>O requirement was still smaller, although the essential oil content in the fruits

and quality (Carvone content) was not appreciably influenced by fertilizer application. Coriander requires smaller N application (maximum 60 kg N/ha) than caraway and its need of  $K_2O$  is greater than that of  $P_2O_5$ . The essential oil content in coriander fruits increased with an increase in fertilizer application. Anise showed a small increase in the seed yield as influenced by the fertilizer application but there was a substantial increase in the essential oil content (upto 24%) with nutrient application, especially  $P_2O_5$  which gave good results.

Duhan et al. (1974) in case of Dill (Anethum graveolens) reported that the highest seed yield of 7.89 q/ha was obtained when plants were sown in the first half of October and given the highest fertilizer rate (90 kg N/ha).

Balbsa et al. (1975) conducted experiments on phosphorus nutrition in Ammi majus and reported that different levels of P (0-100 kg/Feddon) did not show any effect on plant height, number and size of umbels and weight of 100 dry fruits.

Pillai and Bhominathan (1975) reported that the highest seed yield (866 kg/ha) was obtained by the application of 20 N, 40  $P_2O_5$  + 20  $K_2O$  which was significantly superior over no fertilizer treatment. The increased yield in this instance was 25 per cent.

Dill (Anethum sowa) when applied with 60 kg N and 30 kg P<sub>2</sub>O<sub>5</sub> per hectare produced the higher growth and yield of seeds and there was no increase in essential oil content at higher N and P levels (Afridi et al., 1978).

In case of coriander (Coriandrum sativum), Singh et al. (1979) reported that plants receiving 90 kg N/ha gave the best results of yield (over 6 q/ha), plant height (88.75 cm) and number of umbels (7.96/plant).

In Karnataka, to obtain a good yield of coriander application of 36 kg N, 36 kg P<sub>2</sub>O<sub>5</sub> and 36 kg K<sub>2</sub>O per hectare along with 6000 kg of FYM or compost under rainfed condition is recommended. By the application of these practices an yield of about 5-7.5 quintals of coriander seeds per hectare could be obtained (Anon., 1981).

Trivedi (1981) and Yadav and Gupta (1981) found that the optimum dose of nitrogen and phosphorus for Anise was 20:30 kg/ha and 40:30 kg/ha, respectively. The fertilizer application did not affect the oil content but improved the total recovery of oil due to the increase of seed yield per hectare.

Bains et al. (1982) reported that celery (Apium graveolens) yield increased consistently with the increase in the level of N. Application of N at 100 kg/ha and higher

doses were significantly superior over control, whereas, the phosphorus application induced non-significant increase in yield.

Gupta (1982) in case of Dill (Anethum graveolens) reported that increasing levels of nitrogen enhanced the plant height upto a level of 40 kg/ha. Further, the crop yield showed that all doses of nitrogen and phosphorus differed significantly and there was thus a linear effect of nitrogen and phosphorus. The best results were obtained from the combination of N (60 kg) and  $P_2O_5$  (40 kg/ha) (0.706 kg/10 sq.m.), although the oil content did not differ significantly.

Application of 20-30 kg N, 40 kg  $P_2O_5$  and 20 kg  $K_2O$  per hectare along with 10 tonnes of FYM in Lam-C.S.4 coriander resulted in the yield ranging from 14 to 15 q of dried seed per hectare. Ajwan, Omma-Lam-Selection-II when applied with 20 kg N, 40 kg  $P_2O_5$  and 20 kg  $K_2O$  and 5 tonnes of FYM gave an yield of 10 q/ha (Anon., 1984a).

Ibrahim et al. (1984) reported that the dry matter yield, N and P uptake of roots and vegetative mass of Ammi visnaga were significantly increased by N application upto 60 kg/ha. The application of P upto 30 kg/ha significantly increased the dry matter yield and uptake of N and P by the vegetative mass.

With regard to nitrogen requirement of Ammi majus, Duhan et al. (1985) reported that the crop which was sown in the second fortnight of October and applied with 90 kg N/ha gave the highest seed yield of good quality.

Ghosh et al. (1985) reported that in case of coriander (Coriandrum sativum), the nitrogen application at 60 kg/ha markedly increased all the yield attributes like plant height (54.50 cm), number of primary branches per plant (1.85), number of secondary branches per plant (7.16), number of umbels per plant (21.85), number of seeds per umbel (19.57), 1000 seed weight (10.75g) and ultimately the yield (20.05q) per hectare. On the other hand, phosphorus application at various levels had no appreciable effect on those characters except the yield which was maximum (18.09 q/ha) when applied with 40 kg P<sub>2</sub>O<sub>5</sub> per hectare. Interaction effect of NP at 60 kg N and 40 kg P per hectare was found to influence greatly the yield (20.6 q/ha).<sup>1</sup>

Pareek and Sethi (1985) reported that an application of 50 kg N/ha significantly increased the plant height (75.8 cm), number of branches per plant (13.2), number of umbles per plant (13.2) and finally seed yield (11.2 q/ha) by 17.7, 32.0, 26.9 and 18.1 per cent, respectively over the control in coriander. Higher level of nitrogen (90 kg/ha) only marginally increased the seed yield but the difference between 60 and 90 kg N/ha was statistically non-significant.<sup>1</sup>

In case of Anise (Pimpinella anisum), Sethi (1985) reported that the application of 80 kg N/ha (in three splits of 40 + 20 + 20 kg each) increased the seed yield by 94 per cent over control. This also resulted in the increase of oil yield from 6.53 to 12.62 kg/ha. However, application of phosphorus did not show any effect on seed yield. The oil content in seed and its quality were not affected by the nitrogen and phosphorus treatments.

### 2.2.2 Effect of different spacings on growth, yield and essential oil content of related umbelliferous crops

Singh (1963) suggested that the spacing of 45x30 cm was optimum to obtain maximum yield of Ammi majus and Ammi visnaga at Chakarta.

El-Hamidi and Ahmed (1966) observed a positive correlation in plant growth with oil content in the fruits of cumkn (Cuminum cyminum).

Bradu and Atal (1970) recommended a spacing of 90x60 cm as optimum for Ammi majus under Jammu condition.

In Karnataka, coriander seeds are sown by drill in rows at 20 cm apart by adjusting the sowing to drop the

seeds at a distance of about 15 cm within the row for seed crop of coriander (Anon., 1981).

Celery (Apium graveolens) when transplanted at a row spacing of 30 cm and applied with 150 kg N/ha gave the highest yield (17.6 q/ha) followed by a row spacing of 45 cm and applied with 150 kg of N/ha which gave 17.0 q/ha of seeds (Bains et al., 1982).

In case of Dill (Anethum graveolens), Gupta (1982) observed that the spacing of 30x30 cm and 45x20 cm resulted in higher crop yield than other treatments. The spacing of 45x20 cm gave a higher total yield than the spacing of 30x30 cm, although the plant population in both the cases remained the same. However, the difference between them was not significant. It was further noted that the closer spacing of 30x20 cm had reduced branching in the crop. The ridge sowing in Tarai region produced better plant growth and resulted in higher yield.

In case of Ammi visnaga, Ahmed et al. (1983) found that plants grown at 20 cm apart produced significantly lower number of umbels (17) per plant when compared with those grown at a distance of 40 and 60 cm apart. The plants raised at 40 cm spacing gave the highest number of umbels (21) per plant. The fruit yield per plant gradually increased

in plantings at wider distances than 20 cm apart and on the other hand, the yield per unit area of fruits was higher when plants were raised at a distance of 20 cm. They also found that the plant height did not differ significantly due to various spacings and the dense cultivation favoured the fruiting in Ammi visnaga plant.

In Andhra Pradesh, coriander (Coriandrum sativum) seeds were drilled adopting a spacing of 28 x 15 cm in between and along the lines. The seeds were then covered with Guntako immediately after sowing, whereas for Ajwan, the recommended spacing was 60x15 cm. The seeds were sown very shallow with seed drill and covered with a brush harrow (Anon., 1984a).

Keeping in view the plant canopy and other cultural practices in order to get high seed yield, Randhawa et al. (1984) suggested that Ammi majus might be planted in rows at 45 cm and at 30 cm spacing within the row. It resulted in seed yield of 11.85 q/ha, plant height (153.35 cm), number of branches (144.9) and number of umbels (93.95) per plant, which was significantly superior over control.

Pareek and Sethi (1985) found that a row spacing of 45 cm was superior over 30 and 60 cm spacing in case of coriander. The yield attributes like plant height (77.7 cm), number of branches per plant (12.8), number of umbels per plant (12.8), number of umbellets per umbel 95.8),

number of grains per umbel (10.1) and grain yield per hectare (10.06 q) had an edge at 45 cm row spacing over others, and it gave 15.1 and 21.4 per cent significantly higher grain yield over 30 and 60 cm row spacings.

## **MATERIAL AND METHODS**

### III MATERIALS AND METHODS

The studies on the effect of nitrogen, phosphorus and spacings on growth, yield and essential oil content in Foeniculum vulgare Mill. were carried out at the Horticultural Research Station, Gandhi Krishi Vignana Kendra, Bangalore, during Rabi season in the year 1984-85.

#### 3.1 Geographical location and climate

The Horticultural Research Station, Gandhi Krishi Vignana Kendra, Bangalore, is located at an elevation of 930 m from MSL on latitude 12°58' North and longitude of 77°35' East. The meteorological data during the crop growth period are presented in Appendix I.

##### 3.1.1 Soil condition

A plain piece of land having red sandy loam type of soil with uniform fertility status was selected for the experiment. The soil samples were collected from a depth of 0-30 cm from the randomly selected spots. The soil samples were analysed for available nitrogen, phosphorus, potash, pH, organic carbon and electrical conductivity. The results of the analysis are furnished in Appendix II.

### 3.1.2 Experimental details

#### 3.1.2.1 Design : Factorial split plot design.

Number of treatment combinations : 36

Number of replications : 3

Gross plot size : 4.2 x 2.4 metres

Net plot size : 3.6 x 1.8 metres

#### 3.1.2.2 Treatments

##### (a) Main plot treatments (Nitrogen and phosphorus) : 6 Nos.

Levels of nitrogen :  $N_0 = 0$  kg/ha

$N_1 = 50$  kg/ha

$N_2 = 100$  kg/ha

Levels of phosphorus :  $P_0 = 0$  kg/ha

$P_1 = 25$  kg/ha

$P_2 = 50$  kg/ha

##### (b) Sub-plot treatments (Spacings or populations) : 4 Nos.

Symbol	Spacings (cm)	No. of rows/plot	No. of plants/row	No. of plants/ plot	No. of plants/ha
$S_1$	60x15	6	12	72	1,11,111
$S_2$	60x20	6	9	54	83,333
$S_3$	45x30	8	6	48	74,074
$S_4$	45x20	8	9	72	1,11,111



PLATE 1. A view of experimental plot

### 3.1.3 Preparation of experimental plot

The experimental area was disc ploughed. Subsequently the weeds were removed, clods were crushed and land was brought to fine tilth. It was divided into required number of main plots and sub-plots. The main and sub-irrigation channels were laid out taking into consideration the gradient of the site. After the formation of main and sub-plots and channels, the main and sub-plot treatments were assigned to the different main and sub-plots in each replication by using the random table. Well decomposed farmyard manure was applied at the rate of 5 kg/plot (15 cart loads per hectare) and mixed well in the soil.

### 3.1.4 Application of fertilizer

The nutrients were applied in the form of straight fertilizers, nitrogen in the form of urea and phosphorus in the form of single superphosphate. Since the soils are rich in potassium content it was not included in this experiment.

### 3.1.5 Time of application

Full dose of phosphorus was applied at the time of sowing seeds, whereas nitrogen was applied subsequently in two equal split doses, that is at 45 days of sowing and at flower initiation, respectively.

### **3.1.6 Sowing of seeds**

The seeds of commercial variety of fennel, procured locally were soaked in water for five days prior to sowing (Anon., 1983b). They were sown on 2nd November 1984 directly into the field at varied spacings. The experimental plots were irrigated regularly and kept free from weeds.

### **3.1.7 Thinning of excess seedlings**

After 45 days from sowing when the seedlings were established in the field, the excess seedlings were thinned out into the respective spacings, leaving one seedling per hill.

### **3.1.8 After cultivation**

The plots were weeded twice in order to keep the plots free from weeds. They were irrigated regularly at a weekly interval. The crop was earthed up after each top dressing of fertilizer (urea) in order to prevent lodging.

### **3.1.9 Plant protection**

Aphids are the serious pest affecting fennel, particularly during flowering stage. To control them effectively, four sprays of 0.03 per cent Dimethoate were given at 10-15 days interval (Anon., 1983b).

### **3.1.10 Stage of harvest and harvesting**

Since all the fruits do not mature at a time harvesting of umbels was done as and when the umbels attained a slight greenish yellow colour. Three harvests of mature umbels were carried out at 10 days interval. The last harvest being done on 18th April 1985. The harvested umbels were then dried under shade and after 8-10 days of drying they were threshed and seeds separated and cleaned by winnowings.

### **3.1.11 Distillation of essential oil**

The distillation of essential oil from the dried fennel seeds was done by hydrodistillation, using Clavenger's apparatus. For distillation, a known weight (50g) of the dry fennel seeds were ground in 'Multiple x Grinder' into a coarse powder and taken in a flask added with water (half the capacity of flask) and distilled for  $1\frac{1}{2}$  hours. During the distillation care was taken to keep the temperature of the condenser sufficiently high to prevent the oil from congealing thereon (Guenther, 1950). The volatile oil that distilled out was condensed and collected in voils.

### **3.1.12 Experimental observations**

Sampling technique : Five plants in each plot were selected at random avoiding the border row plants and they were tagged for taking observations.



PLATE 2. Different stages of the growth of umbel

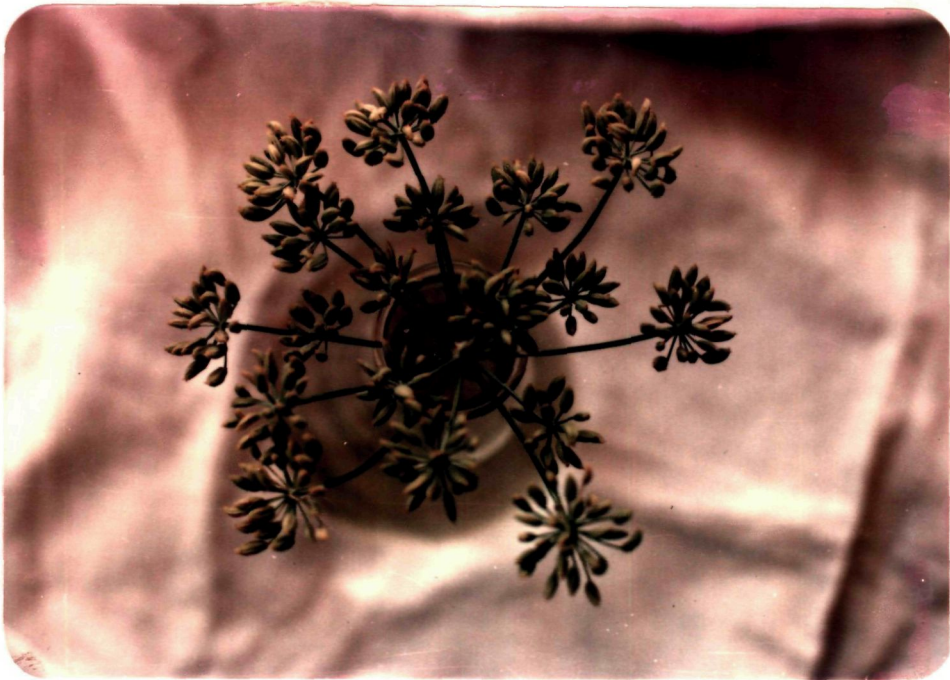


PLATE 3. Umbel at harvesting stage

### 3.1.12.1 Growth parameters

(i) Plant height (cm) : The height of individual plant was measured from the ground level to the tallest growing point at 10 days interval starting from 60 days after sowing.

(ii) Number of branches per plant : The observation on the number of branches was recorded by counting the number of branches in each plant at the final harvest.

(iii) Time taken for first and 50% flowering: After the first plant flowered the observations on flowering were recorded by daily counting the number of plants flowered in each plot.

(iv) Number of umbels per plant : The cumulative number of umbels harvested at each time was used and the total number of umbels per plant was calculated.

(v) Size of the umbel : The diameter of each of the harvested umbels was measured and expressed as the size of the umbel.

(vi) Fresh and dry weight of plant : To observe this five test plants in each plot were cut from ground level and their fresh weight was recorded. Further, they were kept for drying in a hot air oven at 60°C until they attained constant weight and their dry weight was recorded.

### 3.1.12.2 Yield parameters

- (i) Number of fruits per umbel : The data on the number of umbellets per umbel was multiplied with the number of fruits per umbellet and expressed as number of fruits per umbel.
- (ii) Fresh weight of seeds (umbels) per plant : In each of the five plants, freshly harvested umbels from all harvests were weighed along with their seeds and their total was expressed as fresh weight of seeds (umbel) per plant.
- (iii) Dry weight of seeds (fruits) per plant : Freshly harvested umbels were dried under shade. After 8 to 10 days of drying, the umbels were threshed and seeds separated and cleaned by winnowing (Velappan, 1977). The cumulative weight of dried and separated fennel seeds from all the three harvests was used to express as dry weight of seeds per plant.
- (iv) Dry weight of 1000 seeds : To record this observation, 1000 dried seeds of fennel from each plot were counted and weighed.
- (v) Seed yield per hectare : The data on the dry weight of seed per plant was employed to compute the yield per hectare.
- (vi) Percentage oil yield : Percentage oil yield was calculated based on the essential oil yield from each of the seed sample (50g) on dry weight basis.

(vii) Total essential oil yield : Total essential oil yield per hectare was calculated based on the seed yield per hectare.

### 3.1.13 Soil analysis

3.1.13.1 Soil pH The pH of the soil was measured by using a simple electrode pH meter (type Toshniwal Model C 1-2). As suggested by Jackson (1967), soil and water ratio of 1:2.5 was used for pH measurement.

3.1.13.2 Electrical conductivity : The soil and water suspension used for measuring the pH value was filtered and with the help of a conductivity bridge the EC of the solution was measured.

3.1.13.3 Organic carbon : The organic carbon was estimated by Walkely and Black Wet digestion method as described by Piper (1957).

3.1.13.4 Available nitrogen : The available nitrogen content was determined by alkaline permanganate method (Subbaiah and Asija, 1956).

3.1.14.5 Available phosphorus : Bray's No.1 extractant (0.03N ammonium fluoride + 0.025N HCl) method was employed. Phosphorus in the filtered extract was determined by chlorostannous reduced molybdophosphate blue colour method (Jackson, 1967). The intensity of the colour was read using a Spectrophotometer.

**3.1.13.6 Exchangeable potassium** : The neutral ammonium acetate extract of soil was used to determine exchangeable potassium after shaking for 30 minutes on AIMIL flame photometer.

**3.1.14 Plant analysis**

The plants were analysed for their total nitrogen and phosphorus content.

**3.1.14.1 Total nitrogen** : The total nitrogen was determined by Kjeldhal method as outlined by Piper (1957).

**3.1.14.2 Phosphorus** : The phosphorus content in plants was determined by Vanadomolybdate method (Jackson, 1967).

**3.1.15 Statistical analysis and interpretation**

The data on various biometric observations collected during the study were subjected to statistical analysis as per the procedure outlined by Sundararaj et al. (1972).

## **EXPERIMENTAL RESULTS**

## IV EXPERIMENTAL RESULTS

The results of the experiment carried out during Rabi season of 1984 to study the effect of different levels of nitrogen and phosphorus under four different spacings on growth, yield and essential oil content in Foeniculum vulgare Mill. are presented in this chapter.

### 4.1 Growth parameters

#### 4.1.1 Plant height

The data on the plant height as influenced by different levels of nitrogen and phosphorus at different spacings and their interactions are presented in the Tables 1a to 1c and also illustrated in Fig.1.

The effect of different levels of nitrogen on the height of plant was not significant at 60th and 70th day after sowing but it differed significantly among treatments at 80th, 90th day after sowing and also at the time of harvest. In all the cases, N<sub>2</sub> level of nitrogen (100 kg/ha) was found significantly superior to others. At the time of harvest, this treatment (N<sub>2</sub>) recorded the maximum height of plant (113.97 cm) as compared to N<sub>0</sub> level (103.11 cm).

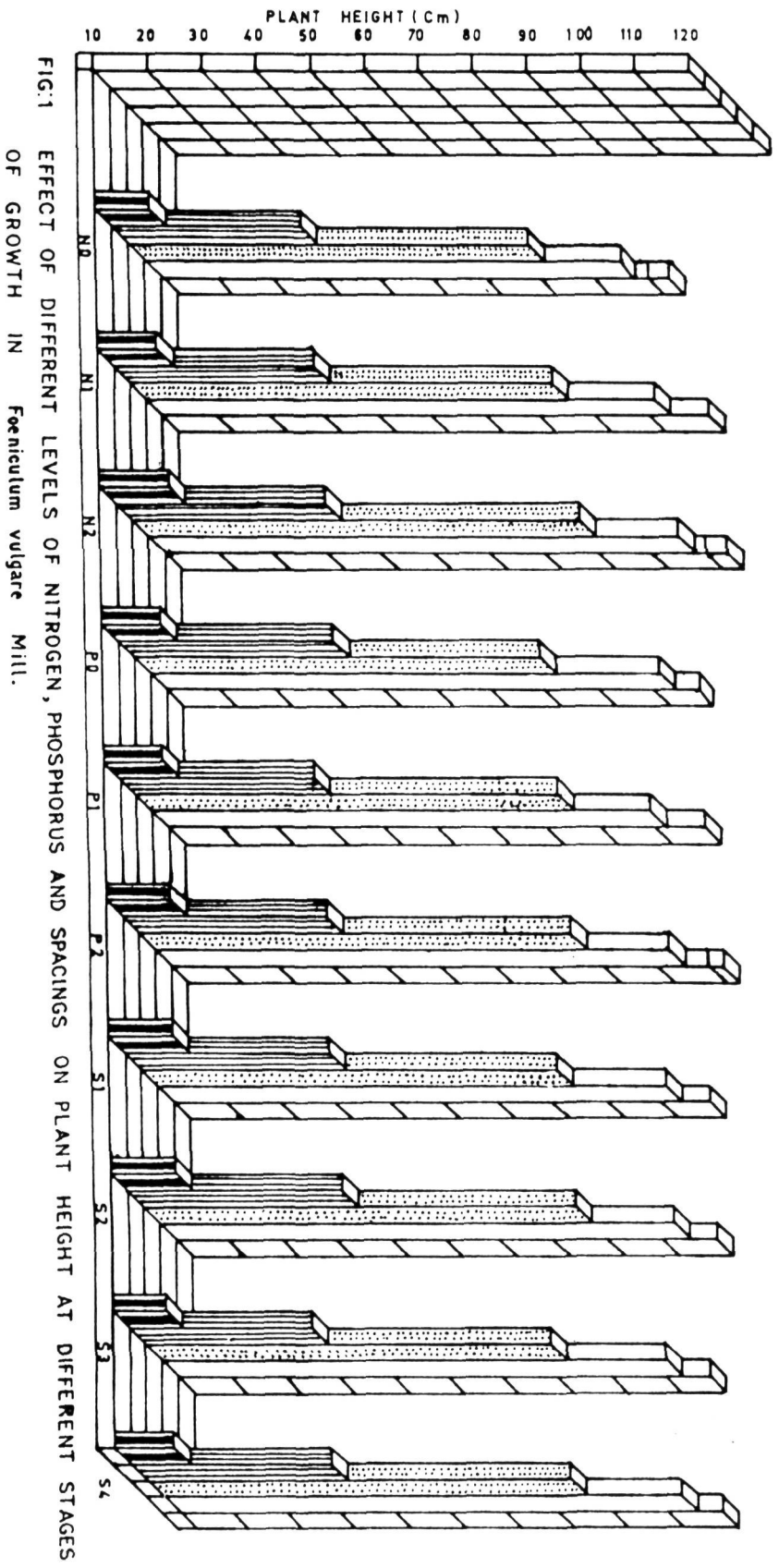
Phosphorus at all the three levels did not influence the plant height throughout the growth period.

Table 1a. Main effect of nitrogen, phosphorus and spacings on plant height (cm) at different growth stages

Treatment	Days after sowing				At harvest
	60	70	80	90	
$N_0$	20.83	44.94	82.66	98.24	103.11
$N_1$	20.87	46.94	87.25	104.33	110.31
$N_2$	21.82	48.71	92.17	108.38	113.97
CD at 5%	NS	NS	5.33**	6.97**	2.79**
$P_0$	20.96	46.66	85.77	104.13	107.66
$P_1$	20.67	45.66	86.48	102.61	108.70
$P_2$	21.90	48.27	89.82	104.40	111.02
CD at 5%	NS	NS	NS	NS	NS
$S_1$	21.63	47.74	86.86	104.45	108.34
$S_2$	21.65	48.18	88.74	104.73	110.02
$S_3$	20.37	44.53	84.60	101.38	108.11
$S_4$	21.05	47.03	87.25	104.32	110.06
CD at 5%	NS	NS	NS	NS	NS

\*\* Significant at 1% probability level

NS = Non-significant



LEGEND

N0 - 0 Kg NITROGEN / ha  
 N1 - 50 Kg NITROGEN / ha  
 N2 - 100 Kg NITROGEN / ha  
 P0 - 0 Kg P<sub>2</sub>O<sub>5</sub> / ha  
 P1 - 25 Kg P<sub>2</sub>O<sub>5</sub> / ha  
 P2 - 50 Kg P<sub>2</sub>O<sub>5</sub> / ha

S1 - 60X15cm  
 S2 - 60X20cm  
 S3 - 45X30cm  
 S4 - 45X20cm

60 DAYS AFTER SOWING  
 70 DAYS AFTER SOWING  
 80 DAYS AFTER SOWING  
 90 DAYS AFTER SOWING  
 FINAL

Table 1b. Interaction effect of Main x Sub- (a) nitrogen and spacings, (b) phosphorus and spacings, on plant height (cm) at different growth stages

Treatment	Days after sowing				At harvest
	60	70	80	90	
<b>(a) N x S</b>					
N <sub>0</sub> S <sub>1</sub>	21.22	44.31	82.77	99.76	103.17
N <sub>0</sub> S <sub>2</sub>	19.94	45.44	83.94	98.17	101.84
N <sub>0</sub> S <sub>3</sub>	21.48	45.73	82.08	96.76	102.14
N <sub>0</sub> S <sub>4</sub>	20.68	44.28	81.84	98.30	105.31
N <sub>1</sub> S <sub>1</sub>	20.42	47.22	90.82	105.11	107.48
N <sub>1</sub> S <sub>2</sub>	22.26	49.84	88.73	106.82	112.86
N <sub>1</sub> S <sub>3</sub>	19.48	43.15	83.23	102.18	111.18
N <sub>1</sub> S <sub>4</sub>	21.33	47.62	86.22	104.03	109.72
N <sub>2</sub> S <sub>1</sub>	23.24	51.68	93.00	108.50	114.38
N <sub>2</sub> S <sub>2</sub>	22.75	49.27	93.55	109.19	115.36
N <sub>2</sub> S <sub>3</sub>	20.15	44.71	88.49	105.20	111.02
N <sub>2</sub> S <sub>4</sub>	21.15	49.18	93.68	110.63	115.15
CD at 5%	NS	NS	NS	NS	NS

Contd.....

Table 1b(contd)

Treatment	Days after sowing				At sowing
	60	70	80	90	
<b>(b) P x S</b>					
P <sub>0</sub> S <sub>1</sub>	22.35	47.93	87.09	104.00	105.95
P <sub>0</sub> S <sub>2</sub>	19.58	45.11	83.69	104.61	107.00
P <sub>0</sub> S <sub>3</sub>	20.22	46.15	85.26	103.44	106.97
P <sub>0</sub> S <sub>4</sub>	21.68	47.48	87.04	104.52	110.77
P <sub>1</sub> S <sub>1</sub>	20.77	46.80	87.71	102.45	107.80
P <sub>1</sub> S <sub>2</sub>	22.13	47.16	89.43	104.97	112.08
P <sub>1</sub> S <sub>3</sub>	19.40	42.43	83.40	100.58	108.16
P <sub>1</sub> S <sub>4</sub>	20.37	46.30	85.43	102.47	106.79
P <sub>2</sub> S <sub>1</sub>	21.75	48.48	91.79	106.93	111.28
P <sub>2</sub> S <sub>2</sub>	23.24	52.28	93.12	104.61	110.98
P <sub>2</sub> S <sub>3</sub>	21.51	45.02	85.14	100.13	109.22
P <sub>2</sub> S <sub>4</sub>	21.11	47.31	89.27	105.97	112.61
CD at 5%	NS	NS	NS	NS	NS

NS = Non-significant

Table 1c. Plant height (cm) as influenced by different levels of nitrogen and phosphorus under four different spacings at different growth stages

Treatment	90 days after sowing				At harvest					
	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	Mean	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	Mean
N <sub>0</sub> P <sub>0</sub>	100.0	97.4	98.8	97.2	98.6	100.7	97.1	101.4	105.1	100.7
N <sub>0</sub> P <sub>1</sub>	94.3	95.6	93.0	92.9	93.9	96.7	98.3	99.0	96.2	96.7
N <sub>0</sub> P <sub>2</sub>	104.8	101.1	97.4	104.7	102.1	112.0	110.0	105.9	114.5	112.0
N <sub>1</sub> P <sub>0</sub>	102.4	105.4	99.3	100.1	101.8	103.7	110.7	104.5	107.2	103.7
N <sub>1</sub> P <sub>1</sub>	106.2	111.2	105.2	107.7	107.6	111.3	122.8	116.5	111.0	111.3
N <sub>1</sub> P <sub>2</sub>	106.7	103.8	101.9	104.2	85.3	107.3	105.0	112.4	110.9	107.3
N <sub>2</sub> P <sub>0</sub>	109.4	111.0	111.0	116.1	109.2	113.3	113.0	114.9	120.0	113.3
N <sub>2</sub> P <sub>1</sub>	106.7	108.0	103.5	106.7	106.2	115.3	115.1	108.8	113.0	115.3
N <sub>2</sub> P <sub>2</sub>	109.2	108.5	101.0	109.0	106.9	114.5	117.8	109.2	112.4	114.5
Mean	104.4	104.7	101.3	104.3		108.3	110.0	108.1	110.3	

R-test CD at 5%      R-test CD at 5%      E-test      CD at 5%

Comparison for any two main plot treatments (NP)      \*      12.06      \*\*      4.831

Comparison for any two sub-plot treatments(spacings)      NS

For comparison of sub-treatments at same level of main treatments      NS

For comparison of main treatment at same level of/or different levels of sub-treatments      NS

\* Significant at 5% probability level    \*\* Significant at 1% probability    NS = Non-significant

Plant height was also not affected by the four different spacings under which they were grown.

With regard to the influence of nutrient levels (NP) on plant height, there was a significant difference observed at 80th and 90th day after sowing, and also at the time of harvest. At 80th day the maximum plant height was recorded at  $N_2P_2$  level (93.55 cm) which was closely followed by  $N_2P_1$  (91.80 cm) and  $N_2P_0$  (91.19 cm) over the control (79.90 cm). However, at 90th day the maximum plant height was recorded at  $N_2P_0$  levels (109.2 cm) followed by  $N_1P_1$  (107.6 cm) and  $N_2P_2$  (106.9 cm). The  $N_0P_1$  treatment recorded the least (93.9 cm), whereas, at the time of harvest the maximum plant height was recorded by  $N_2P_1$  level (115.3 cm) followed by  $N_2P_2$  (114.5 cm),  $N_2P_0$  (113.3 cm) and it was the lowest at  $N_0P_1$  levels (96.7 cm).

None of the interaction effects of NS, PS and NPS were found to influence plant height significantly throughout the growth period.

#### 4.1.2 Number of branches per plant

The data on the number of branches per plant as influenced by different levels of nitrogen and phosphorus at different spacings and their interactions are presented in Tables 2a to 2c and illustrated in Fig.2.

Table 2a. Number of branches per plant as influenced by different levels of nitrogen and phosphorus

Treatment	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	Mean
P <sub>0</sub>	6.93	8.18	7.75	7.62
P <sub>1</sub>	7.48	8.43	8.04	7.98
P <sub>2</sub>	7.50	8.36	8.90	8.26
Mean	7.31	8.33	8.23	
CD at 5% : N		0.45		
CD at 5% : P		0.45		

Table 2b. Interaction effect of (a) nitrogen x spacings and (b) phosphorus x spacings on number of branches per plant

	(a) N x S			(b) P x S		
	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	P <sub>0</sub>	P <sub>1</sub>	P <sub>2</sub>
S <sub>1</sub>	7.09	7.44	7.17	6.81	7.17	7.71
S <sub>2</sub>	7.45	8.34	8.77	7.79	8.30	8.66
S <sub>3</sub>	7.66	9.03	8.67	8.50	8.46	8.39
S <sub>4</sub>	7.03	8.30	8.32	7.38	8.01	8.25
CD at 5%		NS			NS	

NS = Non-significant

Table 2c. Number of branches per plant as influenced by different levels of nitrogen and phosphorus under different spacings

Treatment	$s_1$	$s_2$	$s_3$	$s_4$	Mean
$N_0P_0$	6.63	7.03	7.70	6.38	6.93
$N_0P_1$	7.30	7.66	7.70	7.26	7.48
$N_0P_2$	7.35	7.65	7.58	7.45	7.30
$N_1P_0$	7.48	8.20	9.20	7.85	8.18
$N_1P_1$	6.96	9.20	9.45	8.13	8.43
$N_1P_2$	7.88	8.22	8.45	8.91	8.36
$N_2P_0$	6.33	8.15	8.61	7.93	7.73
$N_2P_1$	7.26	8.03	8.23	8.63	8.04
$N_2P_2$	7.91	10.13	9.16	8.40	8.90
Mean	7.23	8.25	8.45	7.88	

	F-test	CD at 5%
Comparison for any two main plot treatments (NP)	NS	
Comparison for any two sub-plot treatment (spacings)	**	0.406
For comparison of sub-treatments at same level of main treatments	NS	
For comparison of main treatments at same level of/or different levels of sub-treatments	NS	

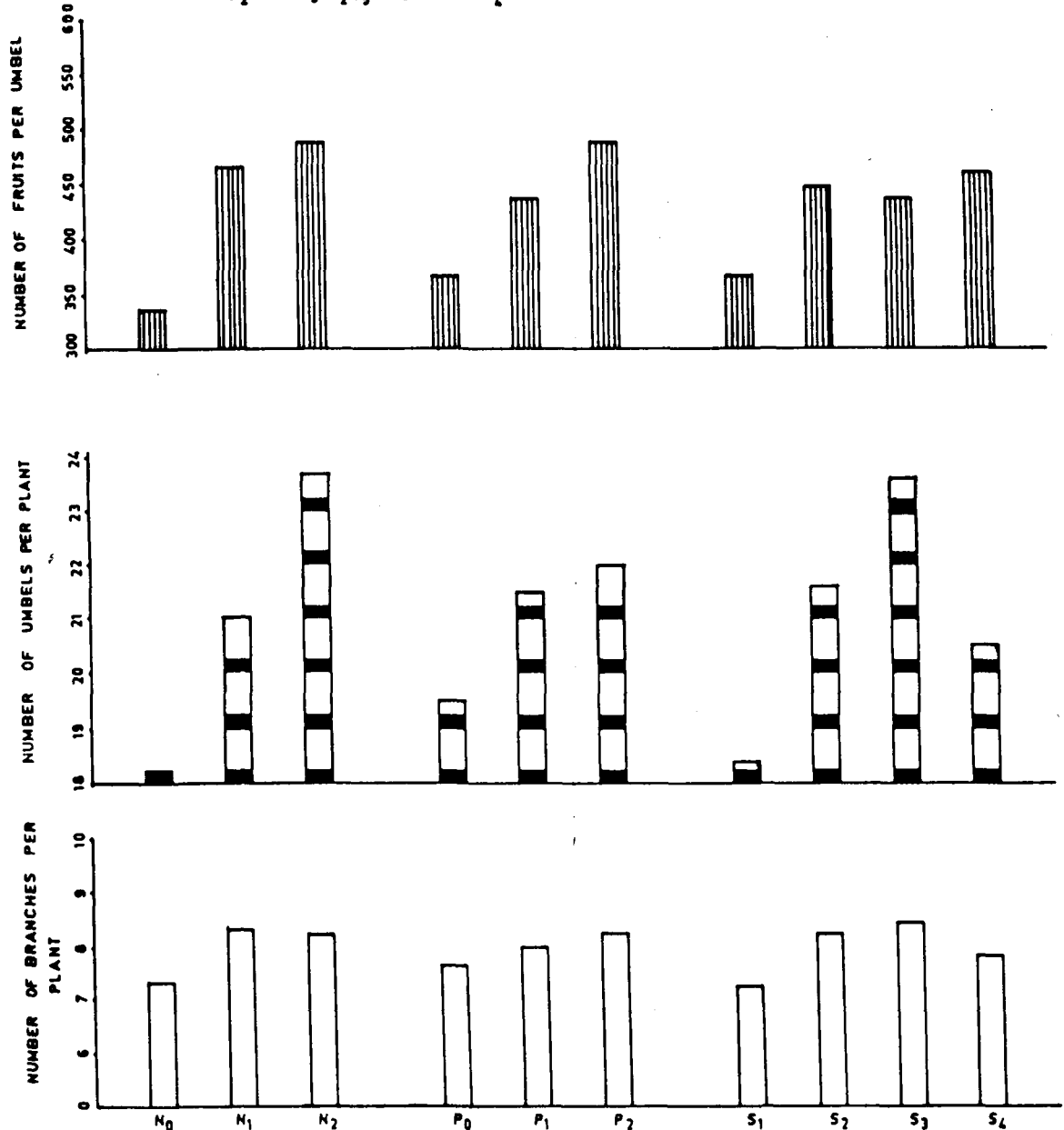
\* Significant at 5% probability level

\*\* Significant at 1% probability level

NS = Non-significant

**LEGEND**

N <sub>0</sub> - 0 Kg N/ha	S <sub>1</sub> - 60 X 15 Cm
N <sub>1</sub> - 50 Kg N/ha	S <sub>2</sub> - 60 X 20 Cm
N <sub>2</sub> - 100 Kg N/ha	S <sub>3</sub> - 45 X 30 Cm
P <sub>0</sub> - 0 Kg P <sub>2</sub> O <sub>5</sub> /ha	S <sub>4</sub> - 45 X 20 Cm
P <sub>1</sub> - 25 Kg P <sub>2</sub> O <sub>5</sub> /ha	
P <sub>2</sub> - 50 Kg P <sub>2</sub> O <sub>5</sub> /ha	



**FIG: 2** EFFECT OF DIFFERENT LEVELS OF NITROGEN, PHOSPHORUS AND SPACINGS ON NUMBER OF BRANCHES, UMBELS PER PLANT AND FRUITS PER UMBEL IN *Foeniculum vulgare* Mill.

Individual effects of nitrogen and phosphorus were significant. Nitrogen at  $N_1$  level (50 kg/ha) produced the maximum number of branches (8.33) which was closely followed by  $N_2$  level (8.23) and significantly superior over  $N_0$  level (7.31). Phosphorus at  $P_2$  level produced the maximum number of branches (8.26) and was significantly superior over  $P_0$  level (7.62).

Plants grown at different spacings exhibited significant differences with regard to number of branches per plant. The maximum number of branches per plant was recorded in the plant grown at  $S_3$  spacing (8.45) followed by  $S_2$  (8.25) which were significantly superior over  $S_1$  and  $S_4$  spacings. The lowest number of branches was recorded in plants grown at  $S_1$  spacing (7.23).

Interaction effects of NP, NS, PS and NPS did not influence the number of branches per plant.

#### 4.1.3 Time taken for first flowering

Observations on the time (days) taken for first flowering as influenced by different levels of nitrogen and phosphorus at different spacings and their interactions are presented in Tables 3a, 3b and 3c.

The time taken for first flowering did not differ significantly among individual effects of different levels of nitrogen, phosphorus and their combinations (NP).

Table 3a. Number of days taken for first flowering as influenced by different levels of nitrogen and phosphorus

Treatments	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	Mean
P <sub>0</sub>	74.74	73.74	74.49	74.33
P <sub>1</sub>	75.33	74.41	74.33	74.69
P <sub>2</sub>	74.16	75.66	73.16	73.66
Mean	74.75	73.94	74.00	
CD at 5% ; N		NS		
CD at 5% ; P		NS		

Table 3b. Interaction effect of (a) nitrogen x spacings and (b) phosphorus x spacings on days taken for first flowering

	(a) N x S			(b) P x S		
	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	P <sub>0</sub>	P <sub>1</sub>	P <sub>2</sub>
S <sub>1</sub>	74.33	73.66	73.10	74.00	73.66	73.44
S <sub>2</sub>	75.22	74.33	73.77	75.22	74.77	73.33
S <sub>3</sub>	75.33	74.33	75.11	74.44	75.77	74.55
S <sub>4</sub>	74.10	73.44	73.99	73.66	74.55	73.33
CD at 5% ; NxS ; NS				CD at 5% ; PxS ; 1.21		

NS = Non-significant

Table 3c. Number of days taken for first flowering as influenced by different levels of nitrogen and phosphorus under different spacings

Treatments	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	Mean
N <sub>0</sub> P <sub>0</sub>	73.66	77.33	75.00	73.00	74.75
N <sub>0</sub> P <sub>1</sub>	75.00	75.00	76.66	74.66	75.33
N <sub>0</sub> P <sub>2</sub>	74.33	73.33	74.33	74.66	74.16
N <sub>1</sub> P <sub>0</sub>	74.00	73.33	73.66	74.00	73.75
N <sub>1</sub> P <sub>1</sub>	73.33	74.66	75.00	74.66	74.41
N <sub>1</sub> P <sub>2</sub>	73.66	75.00	74.33	71.66	73.66
N <sub>2</sub> P <sub>0</sub>	74.33	75.00	74.66	74.00	74.50
N <sub>2</sub> P <sub>1</sub>	72.66	74.66	75.66	74.33	74.33
N <sub>2</sub> P <sub>2</sub>	72.33	71.66	75.00	73.66	73.16
Mean	73.70	74.44	74.92	73.85	

	<u>F-test</u>	<u>CD at 5%</u>
Comparison for any two main plot treatments (NP)	NS	
Comparison for any two sub-plot treatments (spacings)	**	0.609
For comparison of sub-treatments at same level of main treatments	**	1.826
For comparison of main treatments at same level of/or different levels of sub-treatments	**	1.009

\* Significant at 5% probability level  
 \*\* Significant at 1% probability level  
 NS = Non-significant

Whereas, the significant difference was observed in case of different spacings with regard to the time taken for first flowering. The plants grown at  $S_3$  spacing (45x30cm) took the maximum time for first flowering (74.92 days) followed by  $S_2$  spacing which significantly differed with the plants grown at  $S_1$  and  $S_4$  spacing. The minimum time taken for first flowering was observed in plants grown at  $S_1$  spacing (73.70 days).

With regard to interaction effects of PS, time taken for first flowering were found significant. The interactions of  $P_1S_3$  required the maximum time (75.77 days) which was significantly higher than the other interactions. The minimum time (73.33 days) taken for first flowering was noticed in plants receiving the treatments of  $P_2S_2$  and  $P_2S_4$  interactions.

Interaction effects of NPS were also found significant for first flowering. Among the plants grown at  $S_1$  spacing, the plants treated with  $N_0P_1$  level of nutrients required the maximum time (75 days) for the first flowering, which was closely followed by  $N_2P_0$  and  $N_0P_2$  levels (74.33 days). The minimum time taken for first flowering was recorded in plants receiving  $N_2P_2$  level of nutrients (72.33 days).

Among the plants grown at  $S_2$  spacing maximum time taken for first flowering was in control (77.33 days) and the  $N_2P_2$  level of nutrients required the minimum number of days (71.66).

In  $S_3$  spacing, the treatment  $N_0P_1$  required the maximum number of days (76.66) for first flowering which significantly differed with the other treatments, whereas the minimum days (73.66) were recorded in the  $N_1P_0$  treatment which differed significantly.

In case of plants grown at  $S_4$  spacing, the trend with regard to maximum time required for first flowering was same to that of  $S_2$  and  $S_3$  spacing, whereas the plants receiving  $N_1P_2$  level of nutrients required the minimum time (71.66 days) for its first flowering.

#### 4.1.4 Time taken for 50% flowering

Observations on the time taken for 50% flowering as influenced by different levels of nitrogen and phosphorus at different spacings and their interactions are presented in Tables 4a to 4c.

Individual effects of nitrogen, phosphorus and spacings and their interaction effects among the NS, PS and NPS, all of them were found non-significant in respect of the time taken for 50% flowering. Whereas the time taken for 50%

Table 4a. Number of days taken for 50% flowering as influenced by different levels of nitrogen and phosphorus

Treatments	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	Mean
P <sub>0</sub>	83.91	82.74	83.07	83.24
P <sub>1</sub>	84.91	82.58	83.41	83.63
P <sub>2</sub>	83.33	82.66	82.33	82.77
Mean	84.05	82.66	82.93	

CD at 5% : N = NS

CD at 5% : P = NS

Table 4b. Interaction effect of (a) nitrogen x spacings and (b) phosphorus x spacings on number of days taken for 50% flowering

	(a) N x S			(b) Px S		
	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	P <sub>0</sub>	P <sub>1</sub>	P <sub>2</sub>
S <sub>1</sub>	82.88	82.77	82.77	83.44	83.11	83.11
S <sub>2</sub>	84.11	82.55	82.77	83.44	83.66	82.33
S <sub>3</sub>	83.66	82.22	82.99	82.66	83.66	82.55
S <sub>4</sub>	84.44	82.99	83.22	83.44	84.11	83.11

CD at 5% : NxS = NS

CD at 5% : Px S = NS

NS = Non-significant

Table 4c. Number of days taken for 50% flowering as influenced by different levels of nitrogen and phosphorus under different spacings

Treatments	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	Mean
N <sub>0</sub> P <sub>0</sub>	84.33	84.00	83.33	84.00	83.91
N <sub>0</sub> P <sub>1</sub>	83.66	85.33	85.33	85.33	84.91
N <sub>0</sub> P <sub>2</sub>	84.00	83.00	82.33	84.00	83.33
N <sub>1</sub> P <sub>0</sub>	82.33	83.00	82.00	83.66	82.75
N <sub>1</sub> P <sub>1</sub>	82.66	82.00	82.66	83.00	82.58
N <sub>1</sub> P <sub>2</sub>	83.66	82.66	82.00	82.33	82.66
N <sub>2</sub> P <sub>0</sub>	83.66	83.33	82.66	82.66	83.08
N <sub>2</sub> P <sub>1</sub>	83.00	83.66	83.00	84.00	83.41
N <sub>2</sub> P <sub>2</sub>	81.66	81.33	83.33	83.00	82.33
Mean	83.22	83.14	82.96	83.55	

	<u>F-test</u>	<u>CD at 5%</u>
Comparison for any two main plot treatment (NP)	*	1.445
Comparison for any two sub-plot treatments (spacings)	NS	-
For comparison of sub-treatments at same level of main treatments	NS	-
For comparison of main treatments at same level of/or different levels of sub-treatments	NS	-

\* Significant at 5% probability level

\*\* Significant at 1% probability level

NS = Non-significant

flowering differed significantly among different levels of nutrients (NP). The maximum time (84.91 days) taken for 50% flowering was observed at  $N_0P_1$  level followed by  $N_0P_0$  (83.91 days) which significantly differed with other nutrient levels. The minimum time was observed at  $N_2P_2$  level (82.33 days).

#### 4.1.5 Total number of umbels per plant

The data on number of umbels per plant as influenced by different levels of nitrogen and phosphorus at different spacings and their interactions are presented in Tables 5a, 5b and 5c, and illustrated in Fig.2.

Effect of different levels of nitrogen was significant for the number of umbels per plant. The maximum number of umbels per plant was recorded at  $N_2$  level (23.63) which was significantly superior over  $N_1$  and  $N_0$  levels. The minimum number of umbels recorded was at  $N_0$  level (18.25). There was a significant difference among  $N_0$ ,  $N_1$  and  $N_2$  levels.

In case of different spacings influencing the total number of umbels per plant, the plants grown at  $S_2$  spacing recorded the maximum (23.62) which was significantly superior over all other spacings. The minimum number of umbels per plant was recorded in plants grown at  $S_1$  spacing (18.39).

Table 5a. Total number of umbels per plant as influenced by different levels of nitrogen and phosphorus

Treatments	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	Mean
P <sub>0</sub>	16.46	20.70	21.31	19.49
P <sub>1</sub>	18.73	22.33	23.21	21.42
P <sub>2</sub>	19.56	20.05	26.38	22.00
Mean	18.25	21.02	23.63	

CD at 5% : N = 2.63

CD at 5% : P = NS

Table 5b. Interaction effect of (a) nitrogen x spacing and (b) phosphorus x spacing on total number of umbels per plant

	(a) N x S			(b) P x S		
	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	P <sub>0</sub>	P <sub>1</sub>	P <sub>2</sub>
S <sub>1</sub>	17.24	17.55	20.37	17.26	18.11	19.80
S <sub>2</sub>	16.71	23.06	25.02	19.22	22.02	23.55
S <sub>3</sub>	20.88	22.51	26.88	22.13	23.75	24.40
S <sub>4</sub>	18.17	20.97	22.26	19.33	21.82	20.24

CD at 5% : N x S = NS

CD at 5% : P x S = NS

NS = Non-significant

Table 5c. Total number of umbels per plant as influenced by different levels of nitrogen and phosphorus under different spacings

Treatments	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	Mean
N <sub>0</sub> P <sub>0</sub>	16.26	15.86	18.20	15.53	16.46
N <sub>0</sub> P <sub>1</sub>	16.66	17.60	20.86	19.80	18.73
N <sub>0</sub> P <sub>2</sub>	18.80	16.66	23.60	19.20	19.56
N <sub>1</sub> P <sub>0</sub>	16.93	21.40	23.93	20.53	20.70
N <sub>1</sub> P <sub>1</sub>	18.26	24.40	25.40	21.26	22.33
N <sub>1</sub> P <sub>2</sub>	17.46	23.40	18.20	21.13	20.05
N <sub>2</sub> P <sub>0</sub>	18.60	20.40	24.26	22.00	21.31
N <sub>2</sub> P <sub>1</sub>	19.40	24.06	25.00	24.40	23.21
N <sub>2</sub> P <sub>2</sub>	23.13	30.60	31.40	20.40	26.38
Mean	18.39	21.60	23.62	20.47	

	<u>F-test</u>	<u>CD at 5%</u>
Comparison for any two main plot treatments (NP)	*	4.553
Comparison for any two sub-plot treatments (spacings)	**	2.012
For comparison of sub-treatments at same level of main treatments	NS	-
For comparison of main treatments at same level of/or different levels of sub-treatments	NS	-

\* Significant at 5% probability level

\*\* Significant at 1% probability level

NS = Non-significant

Effect of different levels of nutrients (NP) was also found significant. The maximum number of umbels per plant was recorded in plants receiving  $N_2P_2$  level (26.38) followed by  $N_2P_1$  (23.21) and  $N_1P_1$  (22.33). All of these were significantly superior over control which recorded the minimum number of umbels per plant (16.46). Whereas, individual effect of phosphorus and interaction effects of NS, PS and NPS were found non-significant.

#### 4.1.6 Size of the umbel

The data on the size of the umbel (cm) as influenced by different levels of nitrogen and phosphorus at different spacings and their interactions are presented in Tables 6a, 6b and 6c.

Individual effect of nitrogen and phosphorus significantly differed for the size of umbel. The maximum size of umbel was recorded in plants receiving  $N_2$  level of nitrogen (13.00 cm) followed by  $N_1$  level (12.64 cm) which were significantly superior over  $N_0$  level (11.44 cm).

In case of phosphorus,  $P_2$  level recorded the maximum umbel size (12.98 cm) followed by  $P_1$  (12.71 cm) which were significantly superior over  $P_0$  level (11.40 cm).

Size of the umbel also differed significantly in plants grown at different spacings. The maximum umbel

Table 6a. Size of umbel (cm) as influenced by different levels of nitrogen and phosphorus

Treatments	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	Mean
P <sub>0</sub>	10.98	11.33	11.90	11.40
P <sub>1</sub>	11.18	13.46	13.48	12.71
P <sub>2</sub>	12.17	13.13	13.63	12.98
Mean	11.44	12.64	13.00	

CD at 5% : N = 0.736  
P = 0.736

Table 6b. Interaction effect of (a) nitrogen x spacing and (b) phosphorus x spacing on size of umbel (cm)

	(a) N x S			(b) P x S		
	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	P <sub>0</sub>	P <sub>1</sub>	P <sub>2</sub>
S <sub>1</sub>	11.06	12.17	12.69	10.87	12.02	13.03
S <sub>2</sub>	11.30	12.61	13.34	11.23	13.06	12.93
S <sub>3</sub>	12.37	13.27	12.99	12.00	13.44	13.20
S <sub>4</sub>	11.04	12.51	13.00	11.51	12.30	12.73

CD at 5% : N x S = NS                      CD at 5% : P x S = NS

NS = Non-significant

Table 6c. Size of umbel as influenced by different levels of nitrogen and phosphorus under different spacings

Treatments	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	Mean
N <sub>0</sub> P <sub>0</sub>	9.90	10.25	13.10	10.70	10.98
N <sub>0</sub> P <sub>1</sub>	10.70	11.25	11.90	10.87	11.18
N <sub>0</sub> P <sub>2</sub>	12.60	12.41	12.13	11.55	12.17
N <sub>1</sub> P <sub>0</sub>	11.05	11.54	11.28	11.46	11.33
N <sub>1</sub> P <sub>1</sub>	12.66	13.66	14.69	12.82	13.46
N <sub>1</sub> P <sub>2</sub>	12.80	12.63	13.85	13.25	13.13
N <sub>2</sub> P <sub>0</sub>	11.66	11.92	11.62	12.38	11.90
N <sub>2</sub> P <sub>1</sub>	12.70	14.28	13.74	13.23	13.49
N <sub>2</sub> P <sub>2</sub>	13.71	13.82	13.62	13.39	13.63
Mean	11.97	12.41	12.88	12.18	

	<u>F-test</u>	<u>CD at 5%</u>
Comparison for any two main plot treatments (NP)	**	1.274
Comparison for any two sub-plot treatments (spacings)	*	0.579
For comparison of sub-treatments at same level of main treatments	NS	-
For comparison of main treatments at same level of/or different levels of sub-treatments	NS	-

\* Significant at 5% probability level  
 \*\* Significant at 1% probability level  
 NS = Non-significant

size was recorded in plants grown at  $S_3$  spacing (12.88 cm) followed by  $S_2$  spacing (12.41 cm). Size of the umbel in plants grown at  $S_3$  spacing was significantly superior over  $S_1$  and  $S_4$  spacings and minimum size of umbel was recorded at  $S_1$  spacing (11.97 cm).

Effect of different levels of nutrients (NP) on the size of umbel was significantly superior over the control. The maximum size of umbel was recorded in plants receiving  $N_2P_2$  level (13.63 cm) followed by  $N_2P_1$  (13.49 cm) and  $N_1P_2$  (13.13 cm). The control ( $N_0P_0$ ) recorded the lowest umbel size (10.98 cm). Whereas, the interactions, NS, PS and NPS were found to be non-significant.

#### 4.1.7 Fresh weight of plant

The data on fresh weight of plant (g/plant) as influenced by different levels of nitrogen and phosphorus at different spacings and their interactions are presented in Tables 7a, 7b and 7c and also illustrated in Fig.3.

Individual effects of nitrogen and phosphorus were found significant with respect to fresh weight of the plants. Plants receiving  $N_2$  level of nitrogen recorded the maximum fresh weight of plant (51.30 g) followed by  $N_1$  level (48.21g) and were significantly superior over  $N_0$  level which recorded the least fresh weight of plant (31.16g). Phosphorus at  $P_2$  level recorded the maximum fresh weight of plant (45.69g)

Table 7a. Fresh weight of plant (g/plant) as influenced by different levels of nitrogen and phosphorus

Treatments	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	Mean
P <sub>0</sub>	24.56	42.74	53.04	40.11
P <sub>1</sub>	28.23	55.54	50.87	44.88
P <sub>2</sub>	40.70	46.36	50.01	45.69
Mean	31.16	48.21	51.30	

CD at 5% : N = 3.62  
P = 3.62

Table 7b: Interaction effect of (a) Nitrogen x spacing and (b) phosphorus x spacing on fresh weight of plant (g/plant)

	(a) N x S			(b) P x S		
	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	P <sub>0</sub>	P <sub>1</sub>	P <sub>2</sub>
S <sub>1</sub>	26.22	37.33	37.88	30.35	34.71	36.37
S <sub>2</sub>	33.84	55.48	56.40	44.34	52.68	48.70
S <sub>3</sub>	36.14	58.47	61.16	49.23	52.48	54.06
S <sub>4</sub>	28.46	41.56	49.78	36.54	39.65	43.62

CD at 5% : NxS = NS                      CD at 5% : PxS = NS

NS = Non-significant

Table 7c. Fresh weight of plant (g/plant) as influenced by different levels of nitrogen and phosphorus under different spacings

Treatments	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	Mean
N <sub>0</sub> P <sub>0</sub>	20.33	28.13	29.00	20.80	24.56
N <sub>0</sub> P <sub>1</sub>	24.66	29.50	32.43	26.33	28.23
N <sub>0</sub> P <sub>2</sub>	33.66	43.90	47.00	38.26	40.75
N <sub>1</sub> P <sub>0</sub>	34.15	46.56	52.10	38.16	42.74
N <sub>1</sub> P <sub>1</sub>	40.40	68.90	70.33	42.53	55.54
N <sub>1</sub> P <sub>2</sub>	37.46	50.98	53.00	44.00	46.36
N <sub>2</sub> P <sub>0</sub>	36.58	58.32	66.61	50.66	53.04
N <sub>2</sub> P <sub>1</sub>	39.06	59.06	54.68	50.08	50.87
N <sub>2</sub> P <sub>2</sub>	38.00	51.24	62.20	48.60	50.01
Mean	33.81	48.57	51.93	39.93	

	<u>F-test</u>	<u>CD at 5%</u>
Comparison for any two main plot treatments (NP)	**	6.265
Comparison for any two sub-plot treatments (spacings)	**	4.254
For comparison of sub-treatments at same level of main treatments	NS	-
For comparison of main treatments at same level of/or different levels of sub-treatments	NS	-

\*\* Significant at 1% probability level

NS = Non-significant

LEGEND

N<sub>0</sub> - 0 Kg NITROGEN / ha  
 N<sub>1</sub> - 50 Kg NITROGEN / ha  
 N<sub>2</sub> - 100 Kg NITROGEN / ha  
 P<sub>0</sub> - 0 Kg P<sub>2</sub>O<sub>5</sub> / ha  
 P<sub>1</sub> - 25 Kg P<sub>2</sub>O<sub>5</sub> / ha  
 P<sub>2</sub> - 50 Kg P<sub>2</sub>O<sub>5</sub> / ha

S<sub>1</sub> - 60 X 15 Cm  
 S<sub>2</sub> - 60 X 20 Cm  
 S<sub>3</sub> - 45 X 30 Cm  
 S<sub>4</sub> - 45 X 20 Cm

 FRESH WEIGHT  
 DRY WEIGHT

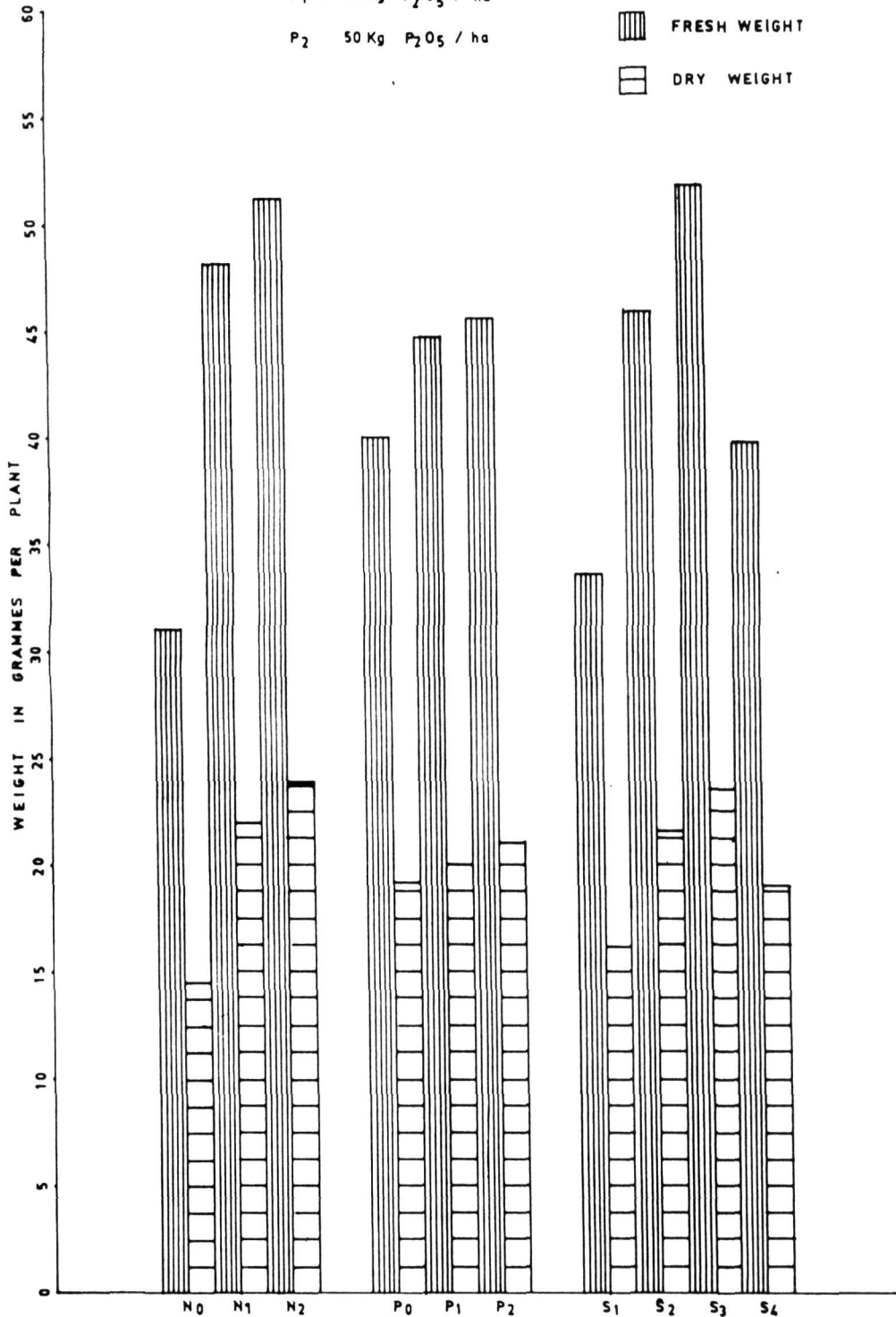


FIG: 3 EFFECT OF DIFFERENT LEVELS OF NITROGEN, PHOSPHORUS AND SPACINGS ON FRESH AND DRY WEIGHT OF PLANT IN *Foeniculum vulgare* Mill.

which was closely followed by  $P_1$  level (44.88g). These were significantly superior over the  $P_0$  level which recorded the least fresh weight of plant (40.11g).

Effect of different combinations of nutrients (NP) on fresh weight of plant was also found significant. Nutrients at  $N_1P_1$  level recorded the highest fresh weight of plant (55.54g) followed by  $N_2P_0$  (53.04g),  $N_2P_1$  (50.87g) and  $N_2P_2$  (50.01g) which were significantly superior over control which recorded the lowest fresh weight of plant (24.56g).

Plants grown at different spacings also differed significantly in their fresh weight. The maximum fresh weight of plant was recorded in plants grown at  $S_3$  spacing (51.93g) followed by  $S_2$  spacing (48.57g) which were significantly superior over  $S_1$  and  $S_4$  spacings. Plants grown at  $S_1$  spacing recorded the lowest fresh weight of plant (33.81g).

Interaction effect of NS, PS and NPS did not differ significantly among themselves.

#### 4.1.8 Dry weight of plant

The observations on dry weight(g) per plant as influenced by different levels of nitrogen and phosphorus at different spacings and their interactions are presented in Tables 8a to 8c and also illustrated in Fig. 3.

Table 8a. Dry weight of plant (g/plant) as influenced by different levels of nitrogen and phosphorus

Treatments	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	Mean
P <sub>0</sub>	13.76	19.95	23.96	19.22
P <sub>1</sub>	13.73	23.62	22.88	20.08
P <sub>2</sub>	16.12	22.21	24.77	21.04
Mean	14.54	21.93	23.87	

CD at 5% : N = 1.90

P = NS

Table 8b. Interaction effect of (a) nitrogen x spacing and (b) phosphorus x spacing on dry weight of plant (g/plant)

	(a) N x S			(b) P x S		
	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	P <sub>0</sub>	P <sub>1</sub>	P <sub>2</sub>
S <sub>1</sub>	12.67	17.73	17.76	15.40	15.41	17.35
S <sub>2</sub>	14.43	23.79	26.80	19.39	23.29	22.34
S <sub>3</sub>	17.40	25.45	28.16	23.32	23.74	23.94
S <sub>4</sub>	13.66	20.74	22.77	18.78	17.87	20.51

CD at 5% : NxS = NS

CD at 5% : PxS = NS

NS = Non-significant

Table 8c. Dry weight of plant (g/plant) as influenced by different levels of nitrogen and phosphorus under different spacings

Treatments	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	Mean
N <sub>0</sub> P <sub>0</sub>	12.00	12.15	18.38	12.53	13.76
N <sub>0</sub> P <sub>1</sub>	11.18	14.70	16.48	12.58	13.73
N <sub>0</sub> P <sub>2</sub>	14.83	16.46	17.33	15.88	16.12
N <sub>1</sub> P <sub>0</sub>	17.00	19.66	23.18	19.96	19.95
N <sub>1</sub> P <sub>1</sub>	17.60	28.60	29.83	18.46	23.62
N <sub>1</sub> P <sub>2</sub>	18.60	23.11	23.33	23.80	22.21
N <sub>2</sub> P <sub>0</sub>	17.22	26.35	28.41	23.86	23.96
N <sub>2</sub> P <sub>1</sub>	17.46	28.58	24.91	22.58	22.88
N <sub>2</sub> P <sub>2</sub>	18.61	27.46	31.16	21.86	24.77
Mean	16.05	21.67	23.67	19.06	

	<u>F-test</u>	<u>CD at 5%</u>
Comparison for two main plot treatments (NP)	**	3.30
Comparison for any two sub-plot treatments (spacings)	**	2.15
For comparison of sub-treatments at same level of main treatments	NS	-
For comparison of main treatments at same level of/or different levels of sub-treatments	NS	-

\*\* Significant at 1% probability level

NS = Non-significant

It is evident from the table that nitrogen at  $N_2$  level recorded the highest dry weight of plant (23.87g), which was significantly superior over  $N_1$  and  $N_0$  levels. The lowest dry weight per plant was recorded in plants receiving  $N_0$  level of nitrogen (14.54 g). There was also a significant difference among the levels of nitrogen ( $N_0$ ,  $N_1$  and  $N_2$ ).

Different levels of nutrients (NP) showed significant effect on the dry weight of the plants. Plants receiving  $N_2P_2$  level of nutrients recorded the highest dry weight per plant (24.77g) followed by  $N_2P_0$  (23.96g),  $N_1P_1$  (23.62g) and  $N_2P_1$  (22.88g) which were significantly superior over control (13.76g). The lowest dry weight per plant was recorded at  $N_0P_1$  level of nutrients (13.73g).

Plants grown at different spacings also differed significantly in their dry weight. The trend on dry weight per plant was also similar as in case of fresh weight per plant. However, the individual effect of phosphorus and interaction effects of NS, PS and NPS on dry weight of plant were all found non-significant.

## 4.2 Yield parameters

### 4.2.1 Number of fruits per umbel

The data on the number of fruits per umbel as influenced by different levels of nitrogen and phosphorus at different

spacings and their interactions are presented in Tables 9a to 9c and illustrated in Fig.2.

Individual effects of nitrogen and phosphorus on number of fruits per umbel differed significantly. Plants receiving  $N_2$  level of nitrogen recorded the maximum number of fruits per umbel (486.66) which was significantly superior over  $N_0$  level which recorded the lowest number of fruits per umbel (337.39).

Phosphorus at  $P_2$  level recorded the maximum number of fruits per umbel (487.08) and was significantly superior over  $P_0$  level which recorded the lowest number of fruits per umbel (363.16).

Effect of NP interaction was significant in respect of number of fruits per umbel. The highest number of fruits per umbel was recorded in plants receiving  $N_2P_2$  (592.50) followed by  $N_1P_1$  (524.37) and  $N_1P_2$  (495.87) and were significantly superior over control ( $N_0P_0$ ) which recorded the lowest number of fruits per umbel (302.12).

Plants grown at different spacings also differed significantly for number of fruits per umbel. The maximum number of fruits per umbel was recorded in plants grown at  $S_4$  spacing (459.91) followed by  $S_2$  (446.63) and  $S_3$  (442.53) and were significantly superior over the plants grown at  $S_1$  spacing which recorded the lowest number of fruits per umbel (367.44).

**Table 9a.** Number of fruits per umbel as influenced by different levels of nitrogen and phosphorus

Treatments	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	Mean
P <sub>0</sub>	302.12	370.42	416.92	363.16
P <sub>1</sub>	337.17	524.37	450.55	437.37
P <sub>2</sub>	372.85	495.85	592.47	487.08
Mean	337.39	463.54	486.66	
CD at 5% : N = 92.42				
P = 92.42				

**Table 9b.** Interaction effect of (a) nitrogen x spacing and (b) phosphorus x spacing on number of fruits per umbel

	(a) N x S			(b) P x S		
	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	P <sub>0</sub>	P <sub>1</sub>	P <sub>2</sub>
S <sub>1</sub>	301.41	389.00	411.90	351.50	333.75	417.08
S <sub>2</sub>	353.16	443.06	543.66	359.75	425.25	493.91
S <sub>3</sub>	370.50	510.73	447.23	324.50	512.83	491.16
S <sub>4</sub>	324.50	511.40	543.83	416.91	417.66	545.16
CD at 5% : NxS = NS			CD at 5% : PxS = NS			

NS = Non-significant

Table 9c. Number of fruits per umbel as influenced by different levels of nitrogen and phosphorus under different spacings

Treatments	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	Mean
N <sub>0</sub> P <sub>0</sub>	265.75	299.25	297.25	346.25	302.12
N <sub>0</sub> P <sub>1</sub>	273.00	382.25	371.50	322.00	337.18
N <sub>0</sub> P <sub>2</sub>	365.50	378.00	442.75	305.25	372.81
N <sub>1</sub> P <sub>0</sub>	415.25	300.50	309.50	456.50	370.43
N <sub>1</sub> P <sub>1</sub>	305.75	565.50	742.25	484.00	524.37
N <sub>1</sub> P <sub>2</sub>	446.00	463.25	480.50	593.75	495.87
N <sub>2</sub> P <sub>0</sub>	373.50	479.50	366.75	448.00	416.93
N <sub>2</sub> P <sub>1</sub>	422.50	508.00	424.75	447.00	450.56
N <sub>2</sub> P <sub>2</sub>	439.75	643.50	550.25	736.50	592.50
Mean	367.44	446.63	442.53	459.91	

	<u>F-test</u>	<u>CD at 5%</u>
Comparison for any two main plot treatments (NP)	**	159.90
Comparison for any two sub-plot treatments (spacings)	*	70.56
For comparison of sub-treatments at same level of main treatments	NS	-
For comparison of main treatments at same level of/or different levels of sub-treatments	NS	-

\* Significant at 5% probability level

\*\* Significant at 1% probability level

NS = Non-significant

However, the interaction effects of NS, PS and NPS were all found non-significant.

#### 4.2.2 Fresh weight of seeds (umbels) per plant

The data on the fresh weight of seeds (umbels) per plant as influenced by different levels of nitrogen and phosphorus at different spacings and their interactions are presented in Tables 10a to 10e and illustrated in Fig.4.

Nitrogen at different levels affected significantly the fresh weight of seeds (g/plant). The maximum fresh weight of seeds was recorded in plants receiving  $N_2$  level of nitrogen (69.02) followed by  $N_1$  level (65.03) and were significantly superior over  $N_0$  level which recorded the lowest fresh weight of seeds (45.19g/plant).

Effect of different levels of nutrients (NP) on fresh weight of seeds per plant were found significant. The highest fresh weight of seeds was recorded in plants receiving  $N_2P_2$  level (71.08) which was closely followed by  $N_2P_0$  (70.16) and  $N_1P_1$  (69.00) which were significantly superior over control which recorded the lowest fresh weight of seeds (40.75 g/plant).

Plants grown at different spacings also differed significantly for fresh weight of seeds. The highest fresh weight of seeds was recorded in plants grown at  $S_3$  spacing (75.74 g/plant) which was significantly superior over all

Table 10a. Fresh weight of seeds (g/plant) as influenced by different levels of nitrogen and phosphorus

Treatments	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	Mean
P <sub>0</sub>	40.74	61.33	70.16	57.41
P <sub>1</sub>	44.24	68.99	65.81	59.68
P <sub>2</sub>	50.58	64.77	71.08	62.15
Mean	45.19	65.03	69.02	

CD at 5% : N = 8.17  
P = NS

Table 10b. Interaction effect of (a) nitrogen x spacing and (b) phosphorus x spacing on fresh weight of seeds (g/plant)

	(a) N x S			(b) P x S		
	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	P <sub>0</sub>	P <sub>1</sub>	P <sub>2</sub>
S <sub>1</sub>	35.33	49.04	49.75	43.24	42.77	48.11
S <sub>2</sub>	48.11	70.73	73.26	62.28	66.55	63.26
S <sub>3</sub>	56.44	80.19	90.57	70.73	77.48	79.00
S <sub>4</sub>	40.88	60.17	62.48	53.40	51.93	58.22

CD at 5% : NxS = 9.18                      CD at 5% : PxS = NS

NS = Non-significant

Table 10c. Fresh weight of seeds (g/plant) as influenced by different levels of nitrogen and phosphorus under different spacings

Treatments	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	Mean
N <sub>0</sub> P <sub>0</sub>	31.40	45.86	48.80	36.93	40.75
N <sub>0</sub> P <sub>1</sub>	33.13	47.46	59.26	37.13	44.25
N <sub>0</sub> P <sub>2</sub>	41.46	51.00	61.26	48.60	50.58
N <sub>1</sub> P <sub>0</sub>	49.20	64.46	74.46	57.20	61.33
N <sub>1</sub> P <sub>1</sub>	47.40	80.66	89.66	58.26	69.00
N <sub>1</sub> P <sub>2</sub>	50.53	67.06	76.46	65.06	64.78
N <sub>2</sub> P <sub>0</sub>	49.13	76.53	88.93	66.06	70.16
N <sub>2</sub> P <sub>1</sub>	47.80	71.53	83.53	60.40	65.81
N <sub>2</sub> P <sub>2</sub>	52.33	71.73	99.26	61.00	71.08
Mean	44.71	64.03	75.74	54.51	

	<u>F-test</u>	<u>CD at 5%</u>
Comparison for any two main plot treatments (NP)	**	14.15
Comparison for any two sub-plot treatments (spacings)	**	5.30
For comparison of sub-treatments at same level of main treatments	NS	-
For comparison of main treatments at same level of/or different levels of sub-treatments	NS	-

\*\* Significant at 1% probability level

NS = Non-significant

other spacings. The lowest fresh weight of seeds was recorded in plants grown at  $S_1$  spacing (44.71 g/plant). There was a significant difference among four spacings ( $S_1$ ,  $S_2$ ,  $S_3$  and  $S_4$ ).

Interaction effect of NS on fresh weight of seeds per plant differed significantly. The maximum fresh weight of seeds was recorded in plants receiving  $N_2S_3$  level of treatments (90.57 g/plant) which was significantly superior over all other treatments. The lowest fresh weight of seeds was recorded in plants receiving  $N_0S_1$  levels of treatments. (35.33 g/plant).

Among the individual effect of phosphorus, and interaction effects of PS and NPS, none was found to differ significantly.

#### 4.2.3 Dry weight of seeds per plant

The data on dry weight of seeds (g/plant) as influenced by different levels of nitrogen and phosphorus at different spacings and their interactions are presented in Tables 11a to 11c and illustrated in Fig. 4.

It is evident from the table 11a that plants receiving nitrogen at  $N_2$  level recorded the maximum dry weight of seeds per plant (25.95g) which was significantly superior over  $N_1$  and  $N_0$  levels. The minimum dry weight of seeds was recorded

Table 11a. Dry weight of seeds (g/plant) as influenced by different levels of nitrogen and phosphorus

Treatments	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	Mean
P <sub>0</sub>	13.43	20.13	26.06	19.87
P <sub>1</sub>	15.11	23.83	25.98	21.64
P <sub>2</sub>	17.48	21.21	25.79	21.50
Mean	15.34	21.72	25.95	

CD at 5% : N = 2.32  
P = NS

Table 11b. Interaction effect of (a) nitrogen x spacing and (b) phosphorus x spacing on dry weight of seeds (g/plant)

	(a) N x S			(b) P x S		
	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	P <sub>0</sub>	P <sub>1</sub>	P <sub>2</sub>
S <sub>1</sub>	12.64	17.40	19.44	15.97	16.44	17.06
S <sub>2</sub>	15.71	23.33	27.82	21.11	23.80	21.95
S <sub>3</sub>	18.80	27.17	31.68	24.13	26.64	26.88
S <sub>4</sub>	14.22	18.99	24.84	18.28	19.68	20.08

CD at 5% : NxS = 2.67      CD at 5% : PxS = NS

NS = Non-significant

Table 11c. Dry weight of seeds (g/plant) as influenced by different levels of nitrogen and phosphorus under different spacings

Treatments	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	Mean
N <sub>0</sub> P <sub>0</sub>	10.86	14.46	15.80	12.60	13.43
N <sub>0</sub> P <sub>1</sub>	11.73	16.06	19.40	13.26	15.11
N <sub>0</sub> P <sub>2</sub>	15.33	16.60	21.20	16.80	17.48
N <sub>1</sub> P <sub>0</sub>	16.93	20.40	24.93	18.26	20.13
N <sub>1</sub> P <sub>1</sub>	17.86	27.80	29.60	20.06	23.83
N <sub>1</sub> P <sub>2</sub>	17.40	21.80	27.00	18.66	21.21
N <sub>2</sub> P <sub>0</sub>	20.13	28.46	31.66	24.00	26.06
N <sub>2</sub> P <sub>1</sub>	19.73	27.53	30.93	25.73	25.98
N <sub>2</sub> P <sub>2</sub>	18.46	27.46	32.46	24.80	25.80
Mean	16.49	22.28	25.88	19.35	

	<u>F-test</u>	<u>CD at 5%</u>
Comparison for any two main plot treatments (NP)	**	4.02
Comparison for any two sub-plot treatments (spacings)	**	1.51
For comparison of sub-treatments at same level of main treatments	NS	-
For comparison of main treatments at same level of/or different levels of sub-treatments	NS	-

\*\* Significant at 1% probability level

NS = Non-significant

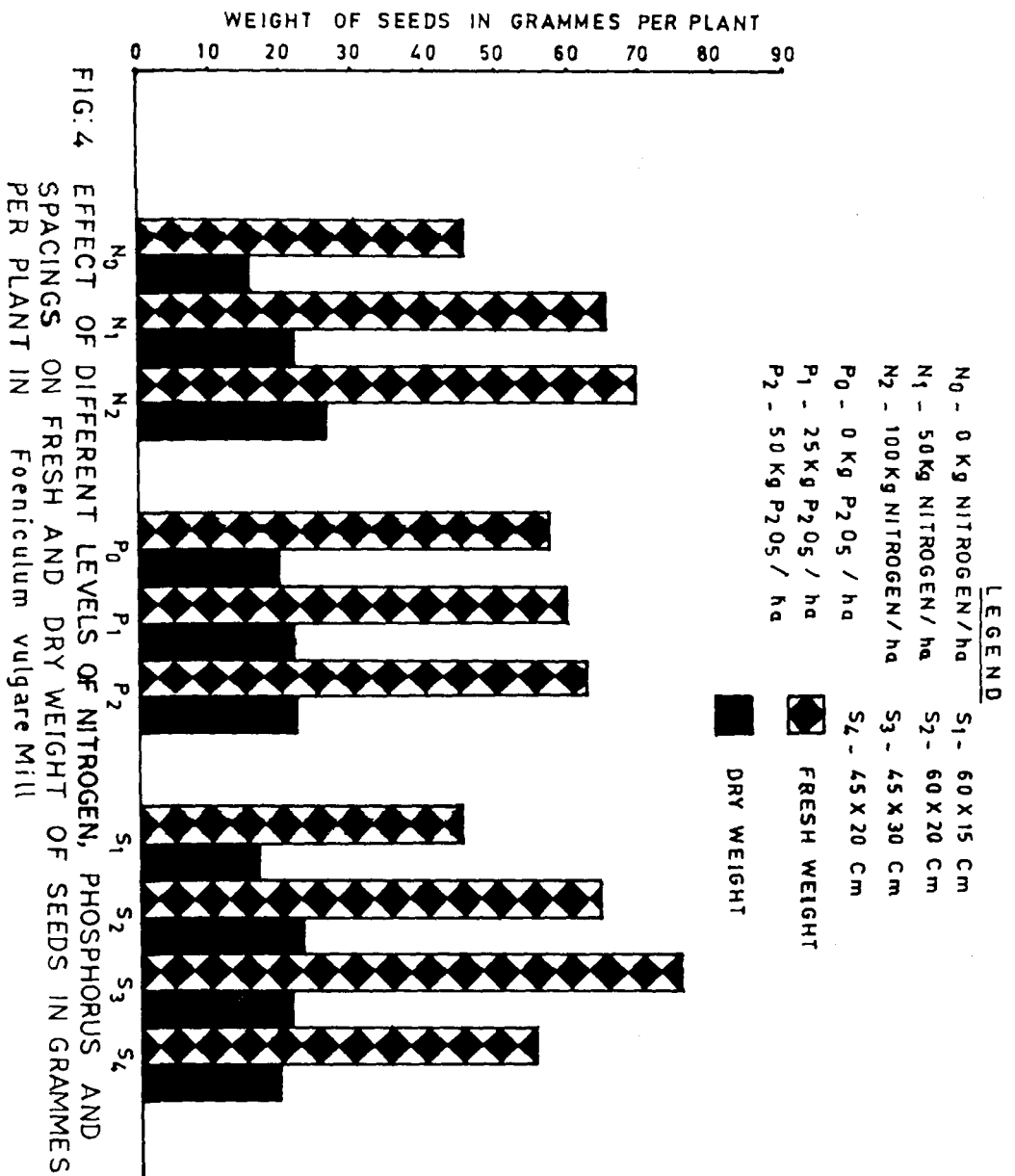
in plants receiving  $N_0$  level of nitrogen. There was a significant difference between the three levels of nitrogen ( $N_0$ ,  $N_1$  and  $N_2$ ).

Effect of different levels of nutrients (NP) on dry weight of seeds was also significantly different. The maximum dry weight of seeds was recorded in plants receiving  $N_2P_0$  level of nutrients (26.06) which was closely followed by  $N_2P_1$  (25.98),  $N_2P_2$  (25.80) and  $N_1P_1$  (23.83) g per plant. These interactions were found significantly superior over control which recorded the lowest dry weight of seeds (13.43 g/plant).

In case of plants grown at different spacings, the trend observed in dry weight of seeds was similar to that of fresh weight of seeds per plant. The maximum dry weight of seeds were produced by the plants grown at  $S_2$  spacing (25.88 g/plant).

In case of interaction effect of NS, again the same trend as in case of fresh weight of seeds was followed here also. The maximum dry weight of seeds (31.68 g/plant) was recorded in plants receiving  $N_2S_3$  levels of treatments which was significantly superior over all other treatments.

Individual effect of phosphorus, interaction effects of PS and NPS were not significant.



#### 4.2.4 Dry weight of 1000 seeds

The data on dry weight of 1000 seeds as influenced by different levels of nitrogen and phosphorus at different spacings and their interactions are presented in Tables 12a to 12c.

It is evident from the tables that individual effect of nitrogen, phosphorus, spacing and interaction effects of NS and NPS differed significantly for the dry weight of 1000 seeds.

Seeds harvested from the plants receiving  $N_2$  level of nitrogen recorded the maximum dry weight of 1000 seeds (6.63 g) which was significantly superior over  $N_1$  and  $N_0$  levels of nitrogen. The lowest dry weight of 1000 seeds was recorded from the plants receiving  $N_0$  level of nitrogen and there was also a significant difference among the three levels of nitrogen ( $N_0$ ,  $N_1$  and  $N_2$ ).

In case of phosphorus, the seeds harvested from the plants receiving  $P_2$  level recorded the maximum dry weight of 1000 seeds (6.57g) which was significantly superior over  $P_0$  level.

Effect of different levels of nutrients (NP) with regard to dry weight of 1000 seeds was found to differ significantly. The seeds harvested from the plants receiving  $N_1P_0$  level of nutrients recorded the maximum dry weight of

Table 12a. Dry weight of 1000 fennel seeds (g) as influenced by different levels of nitrogen and phosphorus

Treatments	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	Mean
P <sub>0</sub>	5.80	6.80	6.62	6.40
P <sub>1</sub>	5.41	6.02	6.50	5.97
P <sub>2</sub>	6.33	6.60	6.78	6.57
Mean	5.84	6.47	6.63	
CD at 5% : N = 0.145				
P = 0.145				

Table 12b. Interaction effect of (a) nitrogen x spacing and (b) phosphorus x spacing on dry weight of 1000 fennel seeds(g).

	(a) N x S			(b) P x S		
	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	P <sub>0</sub>	P <sub>1</sub>	P <sub>2</sub>
S <sub>1</sub>	5.51	5.93	6.40	5.93	5.85	6.06
S <sub>2</sub>	5.95	6.40	6.73	6.75	5.45	6.88
S <sub>3</sub>	5.80	7.01	6.75	6.25	6.78	6.55
S <sub>4</sub>	5.85	6.47	6.63	6.71	5.80	6.80
CD at 5% : NxS = 0.734				CD at 5% : PxS = NS		

NS = Non-significant

Table 12c. Dry weight of 1000 fennel seeds (g) as influenced by different levels of nitrogen and phosphorus under different spacings

Treatments	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	Mean
N <sub>0</sub> P <sub>0</sub>	5.55	6.10	5.50	6.10	5.81
N <sub>0</sub> P <sub>1</sub>	5.40	5.05	5.95	5.25	5.41
N <sub>0</sub> P <sub>2</sub>	5.60	6.70	6.00	7.05	6.33
N <sub>1</sub> P <sub>0</sub>	6.10	7.10	7.00	7.00	6.80
N <sub>1</sub> P <sub>1</sub>	5.55	5.10	7.30	6.15	6.02
N <sub>1</sub> P <sub>2</sub>	6.15	7.00	6.75	6.50	6.60
N <sub>2</sub> P <sub>0</sub>	6.15	7.05	6.25	7.05	6.62
N <sub>2</sub> P <sub>1</sub>	6.60	6.20	7.10	6.10	6.50
N <sub>2</sub> P <sub>2</sub>	6.45	6.95	6.90	6.85	6.78
Mean	5.95	6.36	6.52	6.45	

	<u>F-test</u>	<u>CD at 5%</u>
Comparison for any two main plot treatments (NP)	**	0.252
Comparison for any two sub-plot treatments (spacings)	**	0.150
For comparison of sub-treatments at same level of main treatments	**	0.451
For comparison of main treatments at same level of/or different levels of sub-treatments	**	0.469

\*\* Significant at 1% probability level

seeds (6.80g) which was closely followed by  $N_2P_2$  (6.78g) and  $N_2P_0$  (6.62g) and were significantly superior over control (5.81g).

The dry weight of seeds in plants grown at different spacings also differed significantly. The highest dry weight of 1000 seeds was recorded from the plants grown at  $S_3$  spacing (6.52g) followed by  $S_4$  (6.45g) and  $S_2$  (6.36g) spacings and were significantly superior to  $S_1$  spacing which recorded the lowest dry weight of 1000 seeds (5.95g). Seeds harvested from the plants grown at  $S_3$  spacing were significantly superior over the plants grown at  $S_1$  and  $S_2$  spacings.

Interaction effects of NS were significant for the dry weight of 1000 seeds. Seeds harvested from the plants receiving  $N_1S_3$  level of treatments recorded the maximum dry weight of seeds (7.01g) which was significantly superior over all other treatment levels.

Interaction effects of NPS also differed significantly. In plants grown at  $S_1$  spacing and receiving  $N_2P_1$  level of nutrients recorded the highest dry weight of seeds (6.60g) followed by  $N_2P_2$  (6.45g) which was significantly superior over control (5.55g).

With regard to plants grown at  $S_2$  spacing, the maximum dry weight of seeds was recorded in plants receiving  $N_1P_0$  level of nutrients (7.10g) and was closely followed by  $N_2P_2$

(6.95g). Both the treatments were found significantly superior over control (6.10g).

Among the plants grown at  $S_3$  spacing, the highest dry weight of 1000 seeds was recorded in plants receiving  $N_1P_1$  level of nutrients (7.30g) which was also the highest among all the treatment combinations (NPS) and it was superior over control, which recorded the lowest dry weight of 1000 seeds 5.50g).

In case of plants grown at  $S_4$  spacing the highest dry weight of 1000 seeds (7.05g) was recorded at  $N_2P_0$  and  $N_0P_2$  level of nutrients which was closely followed by  $N_1P_0$  level (7.00g) which were significantly superior over control (6.10g).

Interaction effects of PS did not differ significantly among themselves.

#### 4.2.5 Seed yield per hectare

The data regarding seed yield (q/ha) as influenced by different levels of nitrogen and phosphorus at different spacings and their interactions are presented in Tables 13a to 13c and illustrated in Fig.5.

Effect of different levels of nitrogen found highly significant for seed yield. Application of nitrogen at  $N_2$  level recorded the highest seed yield (23.93g) which was

Table 13a. Seed yield (q/ha) as influenced by different levels of nitrogen and phosphorus

Treatments	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	Mean
P <sub>0</sub>	12.45	18.63	24.04	18.38
P <sub>1</sub>	13.89	21.80	24.01	19.90
P <sub>2</sub>	16.30	19.55	23.74	19.86
Mean	14.21	19.99	23.93	

CD at 5% : N = 2.26

P = NS

Table 13b. Interaction effects of (a) nitrogen x spacing and (b) phosphorus x spacing on seed yield (q/ha)

	(a) N x S			(b) P x S		
	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	P <sub>0</sub>	P <sub>1</sub>	P <sub>2</sub>
S <sub>1</sub>	14.04	18.59	21.60	17.74	17.53	18.95
S <sub>2</sub>	13.08	18.51	23.17	17.58	18.90	18.28
S <sub>3</sub>	13.92	20.86	23.46	17.87	20.46	19.91
S <sub>4</sub>	15.82	22.03	27.50	20.31	22.70	22.31
CD at 5% :	NxS = NS			PxS = NS		

NS = Non-significant

Table 13c. Seed yield as influenced by different levels of nitrogen and phosphorus under different spacings

(Seed yield : g/ha)

Treatments	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	Mean
N <sub>0</sub> P <sub>0</sub>	12.07	12.04	11.70	13.99	12.45
N <sub>0</sub> P <sub>1</sub>	13.03	13.38	14.36	14.81	13.87
N <sub>0</sub> P <sub>2</sub>	17.03	18.83	15.69	18.66	16.30
N <sub>1</sub> P <sub>0</sub>	18.80	16.99	18.46	20.29	18.64
N <sub>1</sub> P <sub>1</sub>	17.64	20.38	24.12	25.06	21.80
N <sub>1</sub> P <sub>2</sub>	19.33	18.15	19.99	20.73	19.55
N <sub>2</sub> P <sub>0</sub>	22.36	23.71	23.45	26.66	24.04
N <sub>2</sub> P <sub>1</sub>	21.92	22.93	22.91	28.29	24.03
N <sub>2</sub> P <sub>2</sub>	20.51	22.88	24.04	27.55	23.74
Mean	18.07	18.25	19.41	21.78	

	<u>F-test</u>	<u>CD at 5%</u>
Comparison for any two main plot treatments (NP)	**	3.92
Comparison for any two sub-plot treatments (spacings)	**	1.97
For comparison of sub-treatments at same level of main treatments	NS	-
For comparison of main treatments at same level of/or different levels of sub-treatments	NS	-

\*\* Significant at 1% probability level

NS = Non-significant

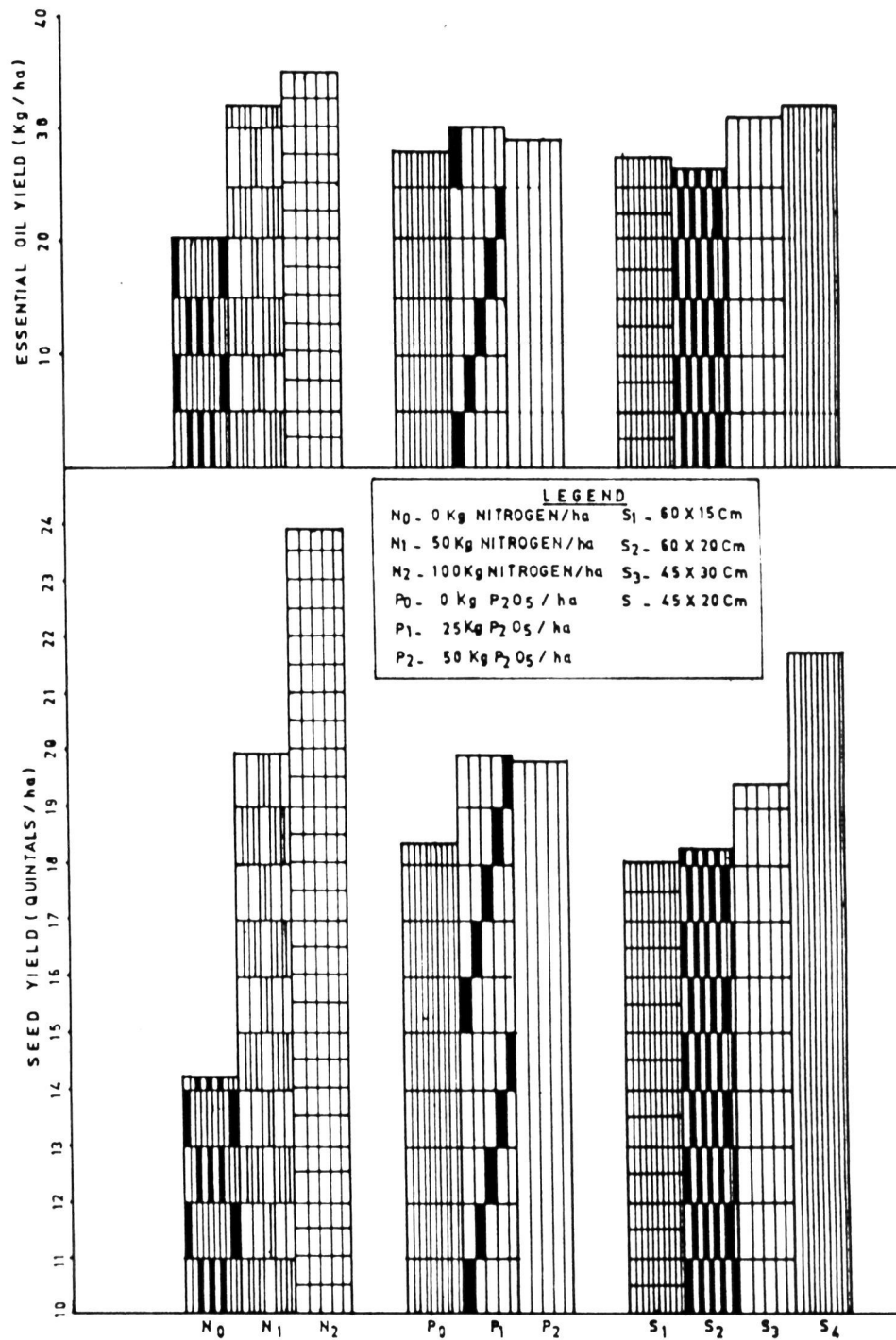


FIG:5 EFFECT OF DIFFERENT LEVELS OF NITROGEN , PHOSPHORUS AND SPACINGS ON SEED YIELD (q/ha) AND ESSENTIAL OIL YIELD(Kg/ha) IN *Foeniculum vulgare* Mill.

significant over  $N_1$  and  $N_0$  levels of nitrogen. The lowest seed yield was recorded at  $N_0$  level and there was a significant difference among the three levels of nitrogen.

The different levels of nutrients (NP) affected the seed yield significantly. The maximum seed yield was recorded in the plants receiving  $N_2P_0$  level of nutrients (24.04q) and it was closely followed by  $N_2P_1$  level (24.03 q) which were significantly superior over control (12.45q) on per hectare basis.

The seed <sup>yield/ha</sup> from the plants grown at different spacings were also found significant. The maximum seed yield was recorded in the plants grown at  $S_4$  spacing (21.78q) which was significantly superior over all other spacings. The lowest seed yield was recorded from the plants grown at  $S_1$  spacing (18.07q).

However, the individual effect of phosphorus and interaction effects of NS, PS and NPS were found non-significant.

#### 4.2.6 Essential oil content in seeds

The data on the essential oil content (percentage on dry weight basis) in seeds as influenced by different levels of nitrogen and phosphorus at different spacings and their interactions are presented in Tables 14a to 14c.

Table 14a. Essential oil content (% on dry weight basis) in seeds as influenced by different levels of nitrogen and phosphorus

Treatments	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	Mean
P <sub>0</sub>	1.31	1.49	1.48	1.43
P <sub>1</sub>	1.43	1.49	1.42	1.45
P <sub>2</sub>	1.41	1.46	1.33	1.40
Mean	1.38	1.48	1.41	
CD at 5% ; N = NS				
P = NS				

Table 14b. Interaction effects of (a) nitrogen x spacing and (b) phosphorus x spacings on essential oil content (% on dry weight basis) in seeds

	(a) N x S			(b) P x S		
	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	P <sub>0</sub>	P <sub>1</sub>	P <sub>2</sub>
S <sub>1</sub>	1.32	1.48	1.41	1.35	1.41	1.45
S <sub>2</sub>	1.31	1.46	1.31	1.33	1.40	1.36
S <sub>3</sub>	1.48	1.53	1.51	1.51	1.56	1.45
S <sub>4</sub>	1.43	1.43	1.41	1.51	1.41	1.35
CD at 5% ; NxS = NS				CD at 5% ; PxS = NS		

NS = Non-significant

**Table 14c.** Essential oil content (% on dry weight basis) as influenced by different levels of nitrogen and phosphorus under different spacings

Treatments	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	Mean
N <sub>0</sub> P <sub>0</sub>	1.15	1.25	1.40	1.45	1.31
N <sub>0</sub> P <sub>1</sub>	1.35	1.40	1.55	1.45	1.43
N <sub>0</sub> P <sub>2</sub>	1.46	1.30	1.50	1.45	1.41
N <sub>1</sub> P <sub>0</sub>	1.50	1.40	1.55	1.50	1.49
N <sub>1</sub> P <sub>1</sub>	1.45	1.45	1.60	1.45	1.49
N <sub>1</sub> P <sub>2</sub>	1.50	1.55	1.45	1.35	1.46
N <sub>2</sub> P <sub>0</sub>	1.40	1.35	1.60	1.60	1.48
N <sub>2</sub> P <sub>1</sub>	1.45	1.35	1.55	1.35	1.42
N <sub>2</sub> P <sub>2</sub>	1.40	1.25	1.40	1.30	1.33
Mean	1.40	1.36	1.51	1.42	

	<u>F-test</u>	<u>CD at 5%</u>
Comparison for any two main plot treatments (NP)	NS	-
Comparison for any two sub-plot treatments (spacings)	*	0.098
For comparison of sub-treatments at same level of main treatments	NS	-
For comparison of main treatments at same level of/or different levels of sub-treatments	NS	-

\* Significant at 5% probability level

NS = Non-significant

The essential oil content in seeds differed significantly in respect of spacings only. The highest essential oil content was recorded in plants grown at  $S_3$  spacings (1.51%) followed by  $S_4$  spacing (1.42%). The essential oil content in seeds of plants grown at  $S_3$  spacing was significantly superior over the seeds obtained from the plants grown at  $S_1$  and  $S_2$  spacing. The lowest essential oil content was recorded in seeds of plants grown at  $S_2$  spacing (1.36%). Whereas, the effect of different levels of nitrogen, phosphorus and interaction effect of NP, NS, PS and NPS were all found non-significant.

#### 4.2.7 Essential oil yield

The data on essential oil yield (kg/ha) as influenced by different levels of nitrogen and phosphorus at different spacings and their interactions are presented in Tables 15a to 15c and illustrated in Fig.5.

Individual effect of nitrogen at different levels significantly influenced the essential oil yield. The maximum yield of oil was recorded at  $N_2$  level of nitrogen (35.28 kg) followed by  $N_1$  level (32.08 kg) which was highly significant over  $N_0$  level and recorded the lowest oil yield (20.38 kg) per hectare.

The effect of different levels of nutrients (NP) on oil yield also differed significantly. The highest oil yield

**Table 15a.** Essential oil yield (kg/ha) as influenced by different levels of nitrogen and phosphorus

Treatments	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	Mean
P <sub>0</sub>	17.91	29.88	37.02	28.27
P <sub>1</sub>	20.20	35.27	35.23	30.23
P <sub>2</sub>	23.04	31.09	33.59	29.23
Mean	20.38	32.08	35.28	
CD at 5% : N = 6.45 P = NS				

**Table 15b.** Interaction effects of (a) nitrogen x spacing and (b) phosphorus x spacing on essential oil yield (kg/ha)

	(a) N x S			(b) P x S		
	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	P <sub>0</sub>	P <sub>1</sub>	P <sub>2</sub>
S <sub>1</sub>	19.10	30.93	32.54	25.80	27.41	29.35
S <sub>2</sub>	17.59	30.74	31.09	24.73	28.87	25.81
S <sub>3</sub>	21.90	33.61	37.47	29.36	32.75	30.86
S <sub>4</sub>	22.94	33.04	40.03	33.19	31.89	30.92
CD at 5% : N x S = NS				CD at 5% : P x S = NS		

NS = Non-significant

**Table 15c.** Essential oil yield (kg/ha) as influenced by different levels of nitrogen and phosphorus under different spacings

Treatment	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	Mean
N <sub>0</sub> P <sub>0</sub>	15.11	15.53	18.46	21.54	17.91
N <sub>0</sub> P <sub>1</sub>	16.99	18.83	23.11	21.86	20.20
N <sub>0</sub> P <sub>2</sub>	25.21	17.38	24.12	25.43	23.04
N <sub>1</sub> P <sub>0</sub>	29.91	25.65	31.11	32.86	29.88
N <sub>1</sub> P <sub>1</sub>	30.74	36.58	38.39	35.37	35.27
N <sub>1</sub> P <sub>2</sub>	32.12	29.98	31.33	30.91	31.09
N <sub>2</sub> P <sub>0</sub>	32.39	32.01	38.51	45.19	37.02
N <sub>2</sub> P <sub>1</sub>	34.50	31.21	36.75	38.46	35.23
N <sub>2</sub> P <sub>2</sub>	30.72	30.06	37.15	36.44	33.59
Mean	27.52	26.47	30.99	32.00	

	<u>R-test</u>	<u>CD at 5%</u>
Comparison for any two main plot treatments (NP)	**	11.162
Comparison for any two sub-plot treatments (spacings)	**	3.77
For comparison of sub-treatments at same level of main treatments	NS	-
For comparison of main treatments at same level of/or different levels of sub-treatments	NS	-

\*\* Significant at 1% probability level

NS = Non-significant

was recorded from the plants receiving  $N_2P_0$  level of nutrients (37.02 kg) which was closely followed by  $N_1P_1$  level (35.27 kg). These were highly significant over the control, which recorded the lowest essential oil yield (17.91 kg) per hectare.

The essential oil yield in seeds of the plants grown at different spacings also differed significantly. The highest oil yield was recovered from the seeds harvested from the plants grown at  $S_4$  spacing (32.00 kg) followed by  $S_3$  spacing (30.99 kg) which was significantly superior over the  $S_1$  and  $S_2$  spacings. The lowest oil yield was obtained in the seeds harvested from the plants grown at  $S_2$  spacing (26.47 kg/ha).

However, the individual effect of phosphorus and interaction effects of NS, PS and NPS were found significant.

### 4.3 Plant analysis

#### 4.3.1 Nitrogen content in whole plant

The data on nitrogen content in plant tissues (% on oven dry basis) as influenced by different levels of nitrogen and phosphorus at different spacings and their interactions are presented in Tables 16a to 16c.

It is evident from the tables that nitrogen content in plant tissue was highly significant among the different levels of nutrients, spacings and their interactions.

**Table 16a.** Nitrogen content in plant tissue (% on oven dry weight basis) as influenced by different levels of nitrogen and phosphorus

Treatments	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	Mean
P <sub>0</sub>	2.204	2.153	2.157	2.171
P <sub>1</sub>	2.015	2.271	2.170	2.152
P <sub>2</sub>	2.192	2.096	2.579	2.289
Mean	2.137	2.173	2.302	

CD at 5% : N = 0.017  
P = 0.017

**Table 16b.** Interaction effects of (a) nitrogen x spacing and (b) phosphorus x spacing on nitrogen content in plant tissue (on oven dry weight basis)

	(a) N x S			(b) P x S		
	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	P <sub>0</sub>	P <sub>1</sub>	P <sub>2</sub>
S <sub>1</sub>	2.067	2.266	2.139	2.053	2.108	2.311
S <sub>2</sub>	2.187	2.171	2.310	2.227	2.177	2.264
S <sub>3</sub>	2.172	2.164	2.330	2.203	2.182	2.281
S <sub>4</sub>	2.123	2.091	2.430	2.202	2.141	2.301

CD at 5% : NxS = 0.028      CD at 5% : PxS = 0.028

Table 16c. Nitrogen content in plant tissue (% on oven dry weight basis) as influenced by different levels of nitrogen and phosphorus under different spacings

Treatments	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	Mean
N <sub>0</sub> P <sub>0</sub>	1.995	2.375	2.175	2.273	2.204
N <sub>0</sub> P <sub>1</sub>	1.988	2.050	2.100	1.923	2.015
N <sub>0</sub> P <sub>2</sub>	2.220	2.135	2.240	2.175	2.192
N <sub>1</sub> P <sub>0</sub>	2.170	2.136	2.205	2.100	2.153
N <sub>1</sub> P <sub>1</sub>	2.323	2.345	2.170	2.245	2.271
N <sub>1</sub> P <sub>2</sub>	2.305	2.033	2.118	1.928	2.096
N <sub>2</sub> P <sub>0</sub>	1.995	2.170	2.30	2.234	2.185
N <sub>2</sub> P <sub>1</sub>	2.015	2.135	2.275	2.55	2.170
N <sub>2</sub> P <sub>2</sub>	2.408	2.625	2.485	2.800	2.579
Mean	2.157	2.223	2.222	2.215	

	<u>F-test</u>	<u>QD at 5%</u>
Comparison for any two main plot treatments (NP)	**	0.030
Comparison for any two sub-plot treatments (spacings)	**	0.016
For comparison of sub-treatments at same level of main treatments	**	0.048
For comparison of main treatments at same level of/or different levels of sub-treatments	**	0.121

\*\* Significant at 1% probability level

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Nitrogen content was the highest (2.302%) in plant tissues which received  $N_2$  level of nitrogen and was significantly superior over  $N_1$  and  $N_0$  levels. The lowest nitrogen content was recorded in the plants receiving  $N_0$  level of nitrogen (2.137%). The three levels of nitrogen ( $N_0$ ,  $N_1$  and  $N_2$ ) also differed significantly among themselves.

In case of plants that received different levels of phosphorus, the nitrogen content in plant tissue was highest at  $P_2$  level (2.289%) which was significantly superior over  $P_1$  and  $P_0$  levels. The lowest nitrogen content was recorded in plants receiving  $P_1$  level of phosphorus.

Effect of different levels of nutrients (NP) on nitrogen content in whole plant was found highly significant. The maximum nitrogen content was recorded in plants receiving  $N_2P_2$  level of nutrients (2.579%), which was significantly superior over all the other nutrient levels. The lowest nitrogen content was recorded in plants that received  $N_0P_1$  level of nutrients (2.015%).

With regard to effect of different spacings on nitrogen content in plant, the highest nitrogen content was recorded in plants grown at  $S_2$  spacing (2.223%) which was closely followed by  $S_3$  spacing (2.222%) and  $S_4$  spacing (2.215%). These were significantly superior over  $S_1$  spacing which recorded the lowest nitrogen content (2.157%).

In NS interaction, the highest nitrogen content was recorded in plants receiving  $N_2S_4$  levels of treatments (2.430%) which was significantly superior over all the other treatment levels. The lowest nitrogen content was recorded in plants receiving  $N_0S_1$  level of treatments (2.067%).

In case of PS interaction, the highest nitrogen content was recorded in plants receiving  $P_2S_1$  level of treatments (2.311%) which was closely followed by  $P_2S_4$  (2.301%) and  $P_2S_3$  (2.281%). These were significantly superior over the other treatment levels. The lowest nitrogen content was recorded in plants that received  $P_0S_1$  levels of treatments (2.053%) which differed significantly with all the other treatment levels.

Among the NPS interactions in  $S_1$  spacing, the plants receiving  $N_2P_2$  level of nutrients recorded the maximum (2.408%) nitrogen content followed by  $N_1P_1$  (2.323%) and  $N_1P_2$  (2.305%) which were significantly superior over the control (1.995%).

Under  $S_2$  spacings the maximum nitrogen content was recorded in plants receiving  $N_2P_2$  level of nutrients (2.625%), which was significantly superior over all other nutrient levels. The lowest nitrogen content (2.033%) was recorded in plants receiving  $N_1P_2$  level of nutrients.

In  $S_3$  spacing, the highest content of nitrogen (2.485%) was recorded in plants receiving  $N_2P_2$  level of nutrients, and was significantly superior over all other nutrient levels. The lowest nitrogen content (2.100%) was recorded in plants receiving  $N_0P_1$  level of nutrients.

With regard to  $S_4$  spacing, the highest nitrogen content (2.800%) was recorded in plants receiving  $N_2P_2$  level of nutrients and was also the highest among all the NPS treatment levels and significantly superior over the rest of nutrient levels among  $S_4$  spacing. The lowest nitrogen content (1.923%) in plant was recorded in the plants receiving  $N_0P_1$  level of nutrients.

#### 4.3.2 Phosphorus content in plant tissue

The data on phosphorus content (% on oven dry weight basis) in plant as influenced by different levels of nitrogen and phosphorus at different spacings and their interactions are presented in Tables 17a to 17c.

It is evident from the tables that neither the main effects of nitrogen, phosphorus and spacings, nor the interaction effects of NP, <sup>NS,</sup> PS and NPS did not show any influence on phosphorus content in plant. Application of phosphorus at different levels failed to influence significantly the phosphorus content in plant tissue.

Table 17a. Phosphorus content in plant (% on oven dry weight basis) as influenced by different levels of nitrogen and phosphorus

Treatments	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	Mean
P <sub>0</sub>	0.184	0.143	0.148	0.158
P <sub>1</sub>	0.167	0.139	0.159	0.155
P <sub>2</sub>	0.148	0.126	0.174	0.150
Mean	0.166	0.136	0.160	

CD at 5% : N = NS  
P = NS

Table 17b. Interaction effects of (a) Nitrogen x Spacing and (b) Phosphorus x Spacing on phosphorus content in plant (% on oven dry weight basis)

	(a) N x S			(b) P x S		
	N <sub>0</sub>	N <sub>1</sub>	N <sub>2</sub>	P <sub>0</sub>	P <sub>1</sub>	P <sub>2</sub>
S <sub>1</sub>	0.150	0.130	0.170	0.152	0.162	0.137
S <sub>2</sub>	0.187	0.120	0.160	0.155	0.153	0.159
S <sub>3</sub>	0.177	0.138	0.155	0.168	0.149	0.153
S <sub>4</sub>	0.153	0.156	0.156	0.158	0.156	0.150

CD at 5% : NxS = NS                      CD at 5% : PxS = NS

NS = Non-significant

Table 17c. Phosphorus content in plant (% on oven dry weight basis) as influenced by different levels of nitrogen and phosphorus under different spacings

Treatments	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>	Mean
N <sub>0</sub> P <sub>0</sub>	0.180	0.208	0.178	0.173	0.184
N <sub>0</sub> P <sub>1</sub>	0.148	0.195	0.158	0.168	0.167
N <sub>0</sub> P <sub>2</sub>	0.123	0.158	0.195	0.118	0.148
N <sub>1</sub> P <sub>0</sub>	0.135	0.120	0.160	0.155	0.143
N <sub>1</sub> P <sub>1</sub>	0.135	0.110	0.140	0.170	0.139
N <sub>1</sub> P <sub>2</sub>	0.120	0.130	0.113	0.143	0.126
N <sub>2</sub> P <sub>0</sub>	0.140	0.138	0.165	0.148	0.148
N <sub>2</sub> P <sub>1</sub>	0.203	0.153	0.150	0.130	0.159
N <sub>2</sub> P <sub>2</sub>	0.168	0.190	0.150	0.190	0.174
Mean	0.150	0.156	0.156	0.155	

Y

	<u>F-test</u>	<u>C.D at 5%</u>
Comparison for any two main plot treatments (NP)	NS	-
Comparison for any two sub-plot treatments (spacings)	NS	-
For comparison of sub-treatments at same level of main treatments	NS	-
For comparison of main treatments at same level of or different levels of sub-treatments	NS	-

NS = Non-significant

## **DISCUSSION**

## V DISCUSSION

The results of the present investigation and their implication on the plant growth and yield parameters are discussed in this chapter. The significance of proper nutrition and plant density in increasing various plant characters such as height of the plant, number of branches, number and size of umbels, etc and the yield parameters such as weight of seeds per plant and its oil content, and the total seed and oil yield has been thoroughly investigated by many workers such as Velappan (1977), Randhawa et al. (1978, 1981), Randhawa & Gill(1982); Paliwal and Singh (1979) and Afridi et al. (1983) in case of fennel and Boshart (1942), Duhan et al. (1974), Afridi et al. (1978), Singh et al. (1979) and Bains et al. (1982) in other various essential oil yielding umbelliferous crops. In their studies they have highlighted the role of major nutrients especially nitrogen, and plant to plant, and row to row spacing in bringing about the desirable changes in both the growth and yield parameters, as both are important from the point of securing greater income out of essential oil yielding plants.

### 5.1 Effect of N, P, Spacings and thier interactions on growth, yield and essential oil content in fennel

#### 5.1.1 Growth parameters

##### 5.1.1.1 Plant height:

The plant height at 80th and 90th day after sowing and also at the time of harvest responded significantly to

nitrogen application. In all the cases, N<sub>2</sub> level (100 kg/ha) was able to increase the plant height greater than other levels (0 and 50 kg N/ha). Similar results have been obtained by Randhawa et al. (1978) in case of fennel; Duhan et al. (1974) in case of Dill and Singh et al. (1979) in coriander. Whereas the plant height did not differ significantly upto 70 days after sowing which might be due to the fact that the assigned dose of nitrogen was split into two equal doses, out of which the first dose was applied after 45 days of sowing and the remaining half dose at the time of flower initiation stage. As the nitrogen is required for the formation of new cells, the vegetative growth is very much influenced by its content. Therefore the effect of nitrogen on plant height was noticed only after 70 days of sowing.

Unlike nitrogen, phosphorus application at all the three levels (0, 25 and 50 kg/ha) did not influence the plant height throughout the growth period. These results are in conformity with the findings of Randhawa and Gill (1982) in fennel, Balbsa et al. (1975) in Ammi majus and Ghosh et al. (1985) in case of coriander.

The plant height was also not affected by the different spacings, under which plants were grown. Similar results were obtained by Randhawa and Gill (1982) in fennel and Ahmed et al. (1983) in case of Ammi visnaga.

However, the plant height was significantly affected by the application of different levels of nutrients (NP).

At the time of harvest, the maximum plant height was recorded at  $N_2P_1$  level ( $N_{100} P_{25}$  kg/ha) followed by  $N_2P_2$  level ( $N_{100} P_{50}$  kg/ha). Thus proving the fact that the efficiency of N uptake was enhanced by the phosphorus application. Similar trends have been observed by Afridi et al. (1978) and Gupta (1982) in case of Dill.

None of the interactions among the NS, PS and NPS was found to influence the plant height significantly throughout the growth period of plants.

#### 5.1.1.2 Number of branches

The effect of nitrogen at  $N_1$  level (50 kg/ha) on the number of branches was found statistically significant over the  $N_0$  level. The nitrogen level beyond 50 kg/ha failed to influence significantly the number of branches per plant. Randhawa et al. (1978) and Randhawa and Gill (1982) also reported the similar results in case of fennel.

Among the phosphorus levels, its application at  $P_2$  level (50 kg/ha) produced the maximum number of branches which was significantly superior over  $P_0$  level.

The plants grown at different spacings differed significantly among themselves. The maximum number of branches were produced by plants grown at  $S_3$  spacing (45x30 cm), similar results were obtained by Randhawa et al. (1984) in Ammi majus and Pareek and Sethi (1985) in

coriander. The lowest number of branches were recorded in plants grown at  $S_1$  spacing (60x15 cm) indicating that closer plant to plant spacing reduced the branching. These results are also in conformity with the findings of Gupta (1982) and Randhawa et al. (1984) in case of Dill and Ammi majus, respectively.

With regard to various NP interactions they failed to influence significantly the number of branches per plant. Randhawa et al. (1981) also recorded the similar findings working in fennel.

#### 5.1.1.3 Time taken for first flowering

The time (days) taken for first flowering did not differ significantly among individual effects of nitrogen, phosphorus and their combinations, whereas the significant differences were observed in case of different spacings. In the plants grown at  $S_3$  spacing (45x30 cm), first flowering was delayed which might be due to the adequate row to row and plant to plant spacing providing the better condition for growth and ultimately extending the vegetative phase. In the plants grown at  $S_1$  spacing (60x15 cm), the first flowering was earliest, perhaps the closer plant to plant spacing, which suppressed the vegetative growth phase would have also reduced the vegetative phase resulting in early flowering.

Interaction effect of PS also differed significantly with respect to first flowering. The first flowering was delayed significantly in plants receiving  $P_1 S_3$  level of treatments, where the plants grown at wider spacing of 45x30 cm and applied with 25 kg of  $P_2 O_5$ /ha, the vegetative growth phase was longer when compared to the other treatments.

Interaction effect of NPS was also found significant with regard to the time taken for first flowering. Under all the four spacings, there was a delay in first flowering in the plants under control and with the application of little phosphorus. Whereas, the first flowering in plants receiving higher rates of nitrogen and phosphorus was earlier.

#### 5.1.1.4 Time taken for 50% flowering

Individual effect of nitrogen, phosphorus, spacing and interactions effect of NS, PS and NPS were found non-significant in respect of the time taken for 50% flowering, whereas, it differed significantly among different levels of nutrients (NP). In case of control ( $N_0 P_0$ ), 50% flowering was delayed significantly over other levels and the earliest 50% flowering was observed in plants receiving higher doses of nitrogen and phosphorus ( $N_2 P_2$ ). This might be due to the application of remaining half dose of nitrogen at the time of flower initiation which along with phosphorus resulted in maximum flowering in the shortest time in the plots without nitrogen.

#### 5.1.1.5 Total number of umbels per plant

With regard to the effect of different levels of nitrogen, significant difference was observed in respect of total number of umbels per plant. The maximum number of umbels per plant was recorded at N<sub>2</sub> level (100 kg/ha). A significant increase in number of umbels was observed with each successive increase in the level of nitrogen and this could be attributed to the adequate availability of nitrogen at critical period. The results are in line with that of Abdullah et al. (1978), Randhawa et al. (1981) in case of fennel and Singh et al. (1979) and Pareek and Sethi (1985) in coriander.

The effect of phosphorus on total number of umbels per plant was found non-significant. These results are in conformity with the findings of Randhawa et al. (1981) in case of fennel, Balbsa et al. (1975) in Ammi majus, and Ghosh et al. (1985) in coriander.

Effect of different levels of nutrient (NP) was also found significant. The maximum number of umbels was recorded in plants receiving the highest levels of nitrogen and phosphorus (N<sub>2</sub>P<sub>2</sub>), which was significantly superior over the control. Similar results in fennel were obtained in a four year trial under the All India Coordinated Spices and Cashew nut Improvement Project at Jagudan (Anon., 1983a).

Different spacings influenced the total number of umbels per plant. The plants growth at  $S_3$  spacing (45x30 cm) recorded the maximum number of umbels, which was significantly superior over all other spacings. Similar kind of results were reported by EL-Gengaihi and Abdullah (1978) in fennel and Randhawa et al. (1984) in case of Ammi majus, whereas the minimum number of umbels per plant were recorded in plants grown at  $S_1$  spacing (60x15 cm). This may be due to the closer plant to plant spacing which led to the lesser number of branches and ultimately less number of umbels per plant. The results are in line with that of Ahmed et al. (1983) in case of Ammi majus.

#### 5.1.1.6 Size of umbel

The maximum size of umbel was recorded in plants receiving  $N_2$  (100 kg/ha) and  $P_2$  (50 kg/ha) doses of nitrogen and phosphorus. The interaction effect of NP was also significant. The maximum size of umbel was recorded in the plants receiving the highest dose ( $N_2P_2$ ). It could be seen from the data that although the nitrogen and phosphorus affected the umbel size upto certain extent but higher doses of them did not have significant effect.

The size of umbel was also influenced significantly in plants grown at different spacings. The maximum size of umbel was recorded in plants grown at  $S_3$  spacing (45x30cm) which differed significantly with those of  $S_1$  (60x15 cm)

and S<sub>4</sub> (45x20 cm) spacings. Thus indicating that the closer plant to plant spacing dose have influence on the size of the umbel rather than the row spacing.

#### 5.1.1.7 Fresh weight of plant

Nitrogen and phosphorus application at N<sub>1</sub> (50 kg/ha) and P<sub>1</sub> (25 kg/ha) levels were able to increase the fresh weight of plant significantly. However, the dose higher than this did not differ among themselves significantly. Interaction effect of NP was also significantly superior at N<sub>1</sub>P<sub>1</sub> level which recorded the maximum fresh weight of plant.

The plants grown at S<sub>3</sub> spacing (45x30 cm) recorded the maximum fresh weight of plant which was significantly superior over the plants grown at S<sub>1</sub> (60x15 cm) and S<sub>4</sub> (45x20 cm) spacings, whereas the plants grown at S<sub>1</sub> spacing recorded the lowest fresh weight. Thus revealing the fact that narrow spacing between plants greatly affected the plant growth, while the wider spacing between rows failed to have much effect either on plant growth or on the fresh weight of the plants.

The above results indicate that the optimum dose of fertilizer coupled with proper row to row and plant to plant spacing enhanced the luxuriant plant growth and produced the increased fresh weight of plant which is proportional to produce more fruit yield.

#### 5.1.1.8 Dry weight of plant

The nitrogen at  $N_2$  level (100 kg/ha) recorded the highest dry weight of plant but it was significantly superior over the plant receiving  $N_1$  and  $N_0$  levels. The dry weight of plant steadily increased with each increasing level of nitrogen, indicating that there was a positive correlation between the nitrogen levels and dry weight of plant. Ibrahim et al. (1984) observed the same kind of results in case of Ammi visnaga.

Application of phosphorus at different levels did not influence the dry weight of the plant. These results are in line with the findings of Ibrahim et al. (1984) in case of Ammi visnaga.

Interactions of nutrients (NP) were found significant for the dry weight of plant. Although the maximum dry weight was recorded in plants receiving higher doses of nutrients ( $N_2P_2$ ) but the significant increase was observed in plants receiving  $N_1P_1$  level ( $N_{50} P_{25}$  kg/ha), which was also significantly superior over the control.

With regard to different spacings, the trend in respect of dry weight per plant was similar to that of fresh weight per plant.

## 5.1.2 Yield parameters

### 5.1.2.1 Number of fruits per umbel

The application of nitrogen at  $N_2$  level (100 kg/ha) although recorded the maximum number of fruits per umbel which was significantly superior over  $N_0$  level but it did not differ with  $N_1$  level (50 kg/ha). This observation is similar to that of Ghosh et al (1985) who observed the highest number of fruits per umbel when the plants were applied with 60 kg N/ha.

Like nitrogen, phosphorus also at  $P_2$  level (50 kg/ha) recorded the maximum number of fruits per umbel although it did not differ significantly with  $P_1$  level (25 kg/ha) but both were significantly superior over  $P_0$  level.

Effect of different levels of nutrients (NP) was found to influence significantly. The  $N_2P_2$  level recorded the maximum number of fruits per umbel although it did not differ significantly with  $N_1P_1$  level. Both these levels were significant over the control.

The results obtained might be because of the active involvement of nutrients (NP) in enhancing the growth and development of reproductive parts in fennel.

Although the maximum number of fruits per umbel was recorded in plants grown at  $S_4$  (45x20cm) followed by  $S_2$  (60x20 cm) but they did not significantly differ with  $S_3$  (45x30 cm)

spacing. These spacings were significantly superior over  $S_1$  (60x15 cm) spacing which recorded the least number of fruits per umbel.

The above results testify that to get the maximum fruitfulness in umbels, appropriate ratio of spacing between plant to plant and row to row is most important factor and any variation in the proportion of this ratio may effect the yield.

#### 5.1.2.2 Fresh weight of seeds (umbels) per plant

In nitrogen application, the maximum fresh weight of seeds (umbels) per plant was recorded at  $N_2$  level (100 kg/ha) although it did not differ significantly with  $N_1$  level (50 kg/ha). Both these levels were found significant over control, whereas individual effect of phosphorus on fresh weight of seeds was non-significant. Although the interaction effect of NP was found significant only upto  $N_1P_1$  level ( $N_{50}P_{25}$  kg/ha) of nutrients which recorded the maximum fresh weight of seeds (except  $N_2P_0$  and  $N_2P_2$  levels).

Plants grown at  $S_3$  spacing (45x30 cm) recorded the highest fresh weight of seeds which was significantly superior over all other spacings. The lowest fresh weight of seeds was recorded in plants grown at  $S_1$  and  $S_4$  spacings, which had the narrow plant to plant spacing of 15 and 20 cm, respectively.

Interaction effect in NS was also found to differ significantly for fresh weight of seeds per plant. The maximum

fresh weight of seeds was recorded in plants receiving  $N_2S_3$  levels of treatments which was significantly superior over all other treatments among NS interaction. The lowest fresh weight of seeds was recorded in plants receiving  $N_0S_1$  level of treatments.

The above results were found to have positive correlation with that of plant growth at various treatments (already discussed). Plant growth parameters like plant height, number of branches, number and size of umbel were directly correlated with fresh weight of seeds per plant.

#### 5.1.2.3 Dry weight of seeds per plant

A gradual significant increase in the dry weight of seeds per plant was observed with each increase in the level of nitrogen. The maximum dry weight of seeds was recorded in plants receiving  $N_2$  level (1000 kg/ha) of nitrogen.

With respect to the individual effect of phosphorus, spacings and interaction effects of NP and NS, the trend observed in case of dry weight of seeds was maintained in fresh weight of seeds per plant also. The  $S_3$  spacing (45x30 cm),  $N_1P_1$  ( $N_{50} P_{25}$  kg/ha) and  $N_2S_3$  ( $N_{100} S_{45x30}$  cm) levels of treatments of spacing NP and NS interactions, respectively proved to be significantly superior over the others. With regard to spacings, similar results were reported by Randhawa

et al. (1984) and Ahmed et al. (1983) in case of Ammi Majus and Ammi visnaga, respectively.

#### 5.1.2.4 Dry weight of 1000 seeds

Nitrogen application at  $N_2$  level (100 kg/ha) and phosphorus at  $P_2$  level (50 kg/ha) recorded the maximum dry weight of 1000 seeds, which were significantly superior over the other levels of nitrogen and phosphorus, respectively Ghosh et al. (1985) obtained the similar kind of results in case of coriander with respect to nitrogen application and their interaction (NP) effects were also found significant. However, in the present study, the interaction of  $N_1P_0$  recorded the maximum dry weight of 1000 seeds followed by  $N_2P_2$  level which was significantly superior over control.

In the plants grown at different spacings, the maximum dry weight of 1000 seeds was recorded at  $S_3$  (45x30 cm), which was significantly superior over  $S_1$  and  $S_2$  spacings. The  $S_1$  seeds recorded the lowest dry weight. The seeds produced at  $S_3$  spacing was found healthy, bold and heavy. This might be because there was no overcrowding of plants or as well as of umbels at  $S_3$  spacing, as in case of other spacings which occurred due to narrow plant to plant spacing within the row.

Interaction effect of NS was also found significant with respect to dry weight of 1000 seeds. The maximum dry weight was recorded in the  $N_1 S_3$  level of treatments which was significantly superior over all the other treatments in NS interaction.

Although the interaction effect of NPS was significant, the results among the four spacings with respect to nutrient (NP) levels were not similar to each other and it was highly fluctuating and inconsistent and because of this no general remark could be passed.

#### 5.1.2.5 Seed yield per hectare

Application of nitrogen at different levels on the seed yield was highly significant. The seed yield increased significantly with each increasing level of nitrogen. The maximum seed yield was recorded from the plants receiving  $N_2$  level (100 kg/ha) of nitrogen which was highly significant over to  $N_1$  and  $N_0$  levels. This shows that there is a scope for going to still higher levels of N to obtain higher yield. Same type of results were obtained by Randhawa et al. (1981) in fennel and Bains et al. (1982) in celery. The results obtained are also in line with the findings of Boshart (1942), Velappan (1977), Randhawa et al. (1978) and Paliwal and Singh (1979) in case of fennel.

Application of phosphorus at different levels failed to influence the seed yield of fennel. Similar results have been

obtained in a fertilizer trial conducted under the All India Coordinated Spices and Cashewnut Improvement Project at Jobner (Anon., 1980) in case of fennel and by Boshart (1942) in caraway, Bains et al. (1982) in celery; Sethi (1985) in Anise and Balbsa et al. (1975) in case of Ammi majus, whereas the results are in contrary to the findings of Randhawa et al. (1981) in fennel, where the field experiment was carried out on sandy loam which was low in organic carbon (0.12%) and low in available phosphorus (10 kg/ha).

Effect of different levels of nutrients (NP) on seed yield was also found significant. The maximum seed yield was recorded at  $N_2P_0$  followed by  $N_2P_1$  which were significantly superior over control ( $N_0P_0$ ). Similar kind of results have been obtained at Jagudan in a four year trial conducted under the All-India Coordinated Spices and Cashewnut Improvement Project (Anon., 1983a) and also by Bhati et al. (1984) in fennel.

Plants grown at different spacings recorded the highly significant difference in their seed yields. The maximum seed yield was recorded in  $S_4$  (45x20 cm) which was significantly superior over all other spacings. The results corroborate the findings of Gupta (1982) in case of Dill. Although the seed yield per plant was significantly more in  $S_3$  (45x30 cm), due to the increase in plant

population per hectare in  $S_4$ , the seed yield in this case increased significantly over the other spacings.

For fennel cultivation, a row spacing of 45 cm was found to be optimum. The results correspond to the findings of Velappan (1977) and Randhawa and Gill (1982) in fennel and Randhawa et al. (1984) in case of Ammi majus.

Regarding plant to plant spacing within the row, the plants grew best when planted 30 cm apart and the maximum seed yield per unit area was obtained from the plants at 20 cm distance. The results are in conformity with the findings of El-Gengaihi and Abdullah (1978) in fennel and Ahmed et al. (1983) in case of Ammi visnaga.

#### 5.1.2.6 Essential oil content in seeds

Application of nitrogen, phosphorus and their interactions at various levels did not have any influence on the essential oil content in seeds. The results are in conformity with the findings of Randhawa et al. (1978, 1981) and Randhawa and Gill (1982) in fennel; Boshart (1942) in caraway; Trivedi (1981), Yadav and Gupta (1981), Sethi (1985) in case of Anise and Afridi et al. (1978) and Gupta (1982) in case of Dill.

However, the seeds harvested from the plants grown at different spacings, differed significantly with respect

to their essential oil content. The highest essential oil content was recorded at S<sub>3</sub> (45x30 cm) spacing, where the plant grew best. A positive correlation between plant growth and essential oil content in fruits was observed. Similar results have also been reported by El-Hamidi and Ahmed (1966) in case of fennel and cumin.

#### 5.1.2.7 Essential oil yield per hectare

Nitrogen application at N<sub>2</sub> level recorded the maximum essential oil yield per hectare, although it did not differ significantly with N<sub>1</sub> level but both these levels were highly significant over the control, whereas application of phosphorus at all the levels failed to have any effect on oil yield. The effects of different levels of nutrients (NP) on the oil yield also differed significantly. Although the highest oil yield was recorded from the plants receiving N<sub>2</sub>P<sub>2</sub> level, but the significant difference was observed at N<sub>1</sub>P<sub>1</sub> level (N<sub>50</sub> P<sub>25</sub> kg/ha) which was highly significant over control.

Although there was no difference in essential oil content in seeds due to various nutrients level, the essential oil yield per hectare rose steadily because of the increase in seed yield per hectare due to application of fertilizers. The results are in conformity with the findings of Boshart (1942), Randhawa et al. (1978), Paliwal and Singh (1979) and Bhati et al. (1984).

In plants grown at different spacings, the highest oil yield was recovered from the seeds harvested from the plants grown at  $S_4$  (45x20 cm) which was closely followed by  $S_3$  (45x30 cm). The oil yield produced at  $S_4$  spacing was statistically significant over the  $S_1$  and  $S_2$  spacings only. Although the essential oil content in seed was significantly superior at  $S_3$  spacing, the oil yield in the treatment was increased due to the increase in seed yield at  $S_4$  spacing. However, it did not differ significantly with that of  $S_3$  spacings. The results obtained are in lines with the findings of El-Hamidi and Ahmed (1966), Velappan (1977), El-Gengaihi and Abdullah (1978) and Randhawa and Gill (1982).

### 5.3 Plant analysis

#### 5.3.1 Nitrogen content

Application of nitrogen induced changes in the tissue nitrogen content. As the quantum of N applied to the plant increases, the corresponding tissue N content was also increased significantly. The highest tissue N content of 2.30 per cent was recorded in the plants that received the highest nitrogen dose of 100 kg/ha, revealing the fact that the application of higher dose of nitrogen increases the nitrogen uptake. Similar kind of results were obtained by Ibrahim et al. (1984) in case of Ammi visnaga.

In case of phosphorus application also similar trend was observed. The tissue N content was highest at  $P_2$  level (50 kg/ha) of phosphorus.

Interaction effect of NP was also found significant. The maximum tissue N content was recorded at the highest dose of nutrient level ( $N_2P_2 - N_{100} P_{50}$  kg/ha).

It was observed that application of phosphorus did have a positive effect on nitrogen uptake in case of fennel. The results obtained are in conformity with the findings of Ibrahim et al. (1984) in Ammi visnaga.

With respect to spacings, plants grown at  $S_2$  spacing (60x20 cm) recorded the highest tissue N content, which was closely followed by  $S_3$  spacing (45x30 cm), emphasizing the fact that the wider row to row and plant to plant spacing enabled the plants to draw more nitrogen from the soil.

Among the interaction effect,  $N_2S_4$  ( $N_{100} S_{45x20}$  cm) and  $P_2S_1$  ( $P_{50} S_{60x15}$  cm) treatment levels recorded the maximum tissue N content in case of NS and PS interactions, respectively.

In case of NPS interaction, in general under all the four spacings, the maximum tissue N content was recorded at higher dose of nutrients ( $N_2P_2$ ), indicating that the nitrogen

uptake was positively correlated with that of the fertilizers applied.

### 5.3.2 Phosphorus content

Tissue phosphorus content did not differ significantly when applied in different doses or with different levels of nitrogen under four different spacings. The results revealed that the tissue phosphorus content was not an important attribute for increasing yield and its uptake could not be increased by the application of more phosphatic fertilizers. Since the available phosphorus content in the soil was only 12 kg/ha, it can be concluded that phosphorus has less role to play in growth, yield and essential oil content in fennel. The results are in conformity with the findings of Boshart (1942), Randhawa et al. (1981) in case of fennel, Balbsa et al. (1975), Randhawa et al. (1984) in Ammi majus and Trivedi (1981), Yadav and Gupta (1981) and Sethi (1985) in case of Anise (Pimpinelle anisum).

## **SUMMARY**

## VI SUMMARY

The field experiment was conducted to investigate the effect of nitrogen, phosphorus and spacings on growth, yield and essential oil content in Foeniculum vulgare Mill. at the Horticultural Research Station, Gandhi Krishi Vignana Kendra, Bangalore, during the year 1984-85. The following are the important findings of the investigation.

1. The final plant height responded significantly to N application. In general, as the quantum of nitrogen applied to the plant was increased, there was a corresponding increase in the height of plant. The maximum plant height was ascertained with the highest dose (100 kg/ha) of nitrogen tried. The plant height noticed in case of control plants was significantly lesser than that of observed in the nitrogen applied plots.

Unlike nitrogen, the role of phosphorus in increasing the plant height was not significant, though the plant height was significantly affected by the application of different levels of nutrients (NP). In general, higher dose of nutrients (NP) recorded the maximum height. At the time of harvest, the maximum plant height was recorded at  $N_2P_1$  ( $N_{100} P_{25}$  kg/ha) level which was highly significant over control.

2. An increase in the dose of nitrogen only upto 50 kg/ha resulted in the significant increase in the number of branches, whereas phosphorus at the highest dose (50 kg/ha) produced the maximum number of branches. Plants grown at  $S_3$  spacing (45x30 cm) produced the maximum number of branches per plant.

3. In the plants grown at  $S_3$  spacing (45x30 cm) first flowering was delayed significantly whereas in the case of plants grown at  $S_1$  spacing (60x15 cm), the first flowering was earliest.

Interaction effect of PS differed significantly with respect to first flowering. The first flowering was delayed in plants receiving  $P_1 S_3$  ( $P_{25}$  kg/ha and  $S_{45 \times 30}$  cm) level of treatments. The interaction effect of NPS was also found significant with regard to the time taken for first flowering. In general, it can be summarized that under all the four spacings, there was a delay in first flowering in the plants receiving no fertilizer or little phosphorus, whereas the first flowering was earliest in plants receiving higher rates of nitrogen and phosphorus.

4. The time taken for 50% flowering differed significantly with respect to different levels of nutrients (NP). In case of control, 50% flowering was delayed significantly and the earliest flowering was observed in plants receiving highest doses of nitrogen and phosphorus ( $N_{100} P_{50}$  kg/ha).

5. The nitrogen fertilization had an appreciable effect in increasing the total number of umbels per plant. Significant increase in number of umbels was observed with each successive increase in the level of nitrogen. The maximum number of umbels were recorded at  $N_2$  level (100 kg/ha).

Although phosphorus at different levels did not have any effect on the number of umbels, this along with nitrogen affected it significantly. The maximum number of umbels was recorded at the highest dose of fertilizers ( $N_{100}P_{50}$  kg/ha) and control recorded the lowest number of umbels.

Again in the plants grown at  $S_3$  spacing (45x30 cm), the maximum number of umbels was recorded and it was significantly superior over all other spacings.

6. Size of the umbel responded significantly only upto  $N_1$  ( $N_{50}$  kgs/ha) and  $P_1$  (25 kg/ha) levels of nitrogen and phosphorus, respectively. The combination of NP also influenced significantly on the umbel size but only upto  $N_1P_1$  level.

In the plants grown at  $S_3$  spacing (45x30 cm) the maximum umbel size was recorded.

7. The nitrogen fertilization had an appreciable effect in increasing the fresh weight of plants at all the three

doses tried, but at  $N_1$  level (50 kg/ha), the difference observed was significant.

Like nitrogen, phosphorus also at  $P_1$  level (25 kg/ha) produced the significant increase in fresh weight of plant and the interaction effect of NP also influenced the fresh weight of the plant at  $N_1 P_1$  level.

Again in the plants grown at  $S_3$  spacing (45x30 cm), the maximum fresh weight of plant was recorded.

8. The highest dose of nitrogen (100 kg/ha) resulted in a significant increase in the dry weight of plant over other levels, whereas the phosphorus nutrition was ineffective in bringing about any significant increase in the dry weight of plant.

Like fresh weight of plant, the dry weight of plant also increased significantly only upto  $N_1 P_1$  level of fertilizers.

In case of plants grown at  $S_3$  spacing (45x30 cm), dry weight of plant was highest compared to other spacings.

9. Although the highest doses of nitrogen and phosphorus recorded the maximum number of fruits per umbel, the significant difference was observed only upto  $N_1$  (50 kg/ha) and  $P_1$  (25 kg/ha) levels, respectively. Combination of nitrogen and phosphorus were also found to be significant but only upto  $N_1 P_1$  level.

The plants grown at  $S_4$  spacing (45 x 20 cm) recorded the maximum number of fruits per umbel which was closely followed by  $S_3$  spacing (45x30 cm).

10. Nitrogen application at each increased level increased the fresh weight of seeds (umbel) per plant but the significant difference was observed only at  $N_1$  level (50 kg/ha), whereas phosphorus application at different levels failed to influence the fresh weight of seeds per plant, although the interaction effect of NP was significant at  $N_1 P_1$  level ( $N_{50} P_{25}$  kg/ha).

In case of plants grown at  $S_3$  spacing (45x30 cm), the fresh weight of seeds per plant was maximum and significantly superior over all other spacings.

The interaction effect of NS at  $N_2 S_3$  (N 100 kg/ha and S 45x30 cm) levels of treatment was significantly superior over all other treatments.

11. In case of dry weight of seeds per plant, nitrogen at the highest dose (100 kg/ha) produced the significant increase over other levels.

Like in the fresh weight of seeds per plant, here also, phosphorus at different levels did not have any effect.

With respect to the individual effect of phosphorus, spacings and interaction effect of NP and NS, the trend observed for dry weight of seed per plant was similar to that observed for fresh weight of seeds per plant.

12. Nitrogen and phosphorus at highest doses produced the maximum dry weight of 1000 seeds. Although their combination effects were found significant, it failed to bring about coherent and consistent trend.

Again it was  $S_3$  spacing (45x30 cm) which recorded the maximum dry weight of 1000 seeds.

Among the interaction effects of NS on dry weight of 1000 seeds, the maximum weight was recorded at  $N_1 S_3$  levels of treatment which was significantly superior over all other treatments.

Whereas the interaction effect of NPS though differed significantly the results among the four spacings with respect to nutrients (NP) levels were not similar to each other.

13. The seed yield per hectare was significantly influenced by the levels of nitrogen and it was highest at  $N_2$  level (100 kg/ha) but the application of phosphorus at any level failed to influence the seed yield, although their combinations at  $N_2 P_1$  level ( $N_{100} P_{25}$  kg/ha) produced the maximum seed yield (except  $N_2 P_0$  level).

Plants grown at  $S_4$  spacing (45x20 cm) produced the maximum seed yield per hectare which was significantly superior over all other spacings.

14. Nitrogen and phosphorus fertilization at various levels did not have any influence on essential oil content in seeds but in case of the seeds harvested from the plants grown at  $S_3$  spacing (45x30 cm), essential oil content was found to be more when compared to other spacings.

15. Nitrogen application upto  $N_1$  level (50 kg/ha) brought the significant increase in essential oil yield per hectare, whereas phosphorus fertilization did not have any effect on oil yield, although the combination effect of NP was found significant at  $N_1 P_1$  level ( $N_{50} P_{25}$  kg/ha).

Oil yield per hectare was maximum in case of seeds harvested from the plants grown at  $S_4$  spacing (45x20 cm) which was closely followed by  $S_3$  spacing.

16. With each application of increasing level of nitrogenous fertilizer, there was a significant increase in tissue N content. Like nitrogen, phosphorus application also at its highest dose (50 kg/ha) significantly increased the tissue N content and their combination effect was also found significant at  $N_2 P_2$  level.

In case of plants grown at  $S_2$  spacing (60x20 cm), the maximum tissue N content was recorded.

Among the interaction effect of NS and PS, the treatments levels  $N_2 S_4$  ( $N_{100}$  kg/ha and  $S_{40x20cm}$ ) e

(P<sub>50</sub> kg/ha and S<sub>60x15</sub> cm) recorded the maximum tissue N content, respectively.

Interaction effect of NPS also differed significantly with respect to tissue N content and it was observed that under all the four spacings the maximum tissue 'N' content was recorded at the highest dose of fertilizer (100 P<sub>50</sub> kg/ha).

17. None of the treatment levels and their combinations tried in this study was found to influence significantly the phosphorus content in the plants.

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\* Original not seen.

## **APPENDICES**

APPENDIX I

Meteorological data as recorded at the Horticultural Research Station, G.K.V.K. University of Agricultural Sciences, Bangalore, for the period from October 1984 to May 1985

Month/Year	Mean Temperature (°C)		Sun shine (hr/day)	Mean R.H. (%)	Total rainfall (mm)
	Maximum	Minimum			
October 1984	28.3	18.4	5.7	76	69.6
November 1984	27.8	15.6	9.1	65	0.0
December 1984	25.7	16.5	5.7	71	32.4
January 1985	27.0	15.9	8.4	63	0.0
February 1985	27.7	16.8	7.7	62	47.7
March 1985	31.2	17.5	8.8	51	70.1
April 1985	33.0	20.5	8.5	57	12.3
May 1985	34.5	21.3	9.7	55	14.2

## APPENDIX II

Mechanical and chemical analysis of the composite sample  
taken from the experimental site (0-30 cm)

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I Physical characteristicsMechanical analysis

Coarse sand (%)	..	39.00
Fine sand (%)	..	34.25
Silt (%)	..	7.25
Clay (%)	..	19.50

II Physico-chemical properties

Soil reaction (pH)	..	5.5
Electrical conductivity (EC) (mmhos/cm)	..	0.2

III Chemical properties

Organic carbon (%)	..	0.38
Available Nitrogen (kg/ha)	..	225.25
Available Phosphorus (kg/ha)	..	12.00
Available Potassium (kg/ha)	..	126.00

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