EFFECT OF NITROGEN, PHOSPHORUS LEVELS AND PLANT DENSITIES ON THE GROWTH, YIELD AND QUALITY OF IRRIGATED SAFFLOWER

BY

POWAR ANIL TUKARAM
B. Sc. (Agri.) First Class

A Thesis submitted to the
MAHATMA PHULE AGRICULTURAL UNIVERSITY
RAHURI, Dist. Ahmednagar
(Maharashtra State India)

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE (Agriculture)

in

AGRONOMY

DEPARTMENT OF AGRONOMY

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Approved

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DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
PUNE-411 005

1987

CANDIDATE'S DECLARATION

I, hereby declare that this thesis or part thereof has not been submitted by me or any other person to any other University or Institution for a Degree or Diploma.

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Dated : 31/12 , 1987

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CERTIFICATE

This is to certify that, the thesis entitled, "Effect of Nitrogen, Phosphorus Levels and Plant Densities on the Growth, Yield and Quality of Irrigated Safflower" submitted to the Faculty of Agriculture, Mahatma Phule Agricultural University, Rahuri, District : Ahmednagar (Maharashtra), in partial fulfilment of the requirement for the degree of MASTER OF SCIENCE (AGRICULTURE) in AGRONOMY embodied the results of a piece of bona fide research work carried out by Shri Anil Tukaram Powar, under my guidance and supervision and is of sufficiently high standard to warrant its submission to the University for the award of the said degree. No part of the thesis has been published in any other form.

The assistance and help received during the course of this investigation and source of literature referred to have been duly acknowledged.

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CERTIFICATE

This is to certify that the thesis entitled, "Effect of Nitrogen, Phosphorus Levels and Plant Densities on the Growth, Yield and Quality of Irrigated Safflower" submitted by Shri Anil Tukaram Powar, to the Faculty of Agriculture, Mahatma Phule Agricultural University, Rahuri, in partial fulfilment of the requirement for the degree of MASTER OF SCIENCE (AGRICULTURE) in AGRONOMY embodied the results of a piece of bona fide research work carried out by him under the guidance and supervision of Prof. V.S.Mane, Associate Professor of Agronomy and that no part of the thesis has been submitted for any other degree or publication.

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Dated : 13 1 , 1988.

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Last but never the least, words are small in expressing my heartfelt feelings to my family whose inspiration and sacrifice, enabled me to complete my post-graduate studies.

Pune-411 005,
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(A.P.POWAR)

TABLE OF CONTENTS

Table of contents (contd.) **Page**

Table of contents (contd.) Page

Table of contents (contd.)

LIST OF TABLES

List of tables (contd.) | Page

Table

LIST OF FIGURES

LIST OF ABBREVIATIONS

cm	...	...	Centimetre (s)
g	...	...	Gramme (s)
kg	...	...	Kilogramme (s)
q	...	...	Quintal (s)
^{o}C	...	...	Degree centigrade
t	...	...	Tonne (s)
mm	...	...	Millimetres
in	...	...	Inch
viz.	...	...	Namely
N	...	...	Nitrogen
P	...	...	Phosphorus
S.E.	...	...	Standard Error
C.D.	...	...	Critical difference

ABSTRACT

EFFECT OF NITROGEN, PHOSPHORUS LEVELS AND PLANT DENSITIES ON THE GROWTH, YIELD AND QUALITY OF IRRIGATED SAFFLOWER

By

Anil T. Powar

A candidate for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

(AGRONOMY)

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Research Guide : Prof. V.S.Mane

Department : Agronomy

The investigation on the "Effect of Nitrogen, Phosphorus levels and Plant Densities on the Growth, Yield and Quality of Irrigated Safflower" variety Bhima was conducted during the <u>rabi</u> season of 1985-86 at the Agricultural College Farm, Pune. The experiment was laid out in factorial randomised block designwith three replications. There were four fertilizer levels <u>viz.</u>, 25 kg N + 12.5 kg P_2O_5/ha, 50 kg N + 25 kg P_2O_5/ha, 75 kg N + 37.5 kg P_2O_5/ha and 100 kg N + 50 kg P_2O_5/ha and four plant densities <u>viz.</u>, 2.25 lakh

plants/ha (45 x 10 cm), 1.50 lakh plants/ha (45 x 15 cm), 1.00 lakh plants/ha (45x22.5 cm) and 0.75 lakh plants/ha (45 x 30 cm).

The application of 100 kg N + 50 kg P_2O_5/ha showed beneficial improvement in important growth attributes viz., plant height, spread, number of main and sub-branches and dry matter accumulation/plant. The application of 75 kg N + 37.5 kg P_2O_5/ha and 100 kg N + 50 kg P_2O_5/ha increased number of capsules significantly over 25 kg N + 12.5 kg P_2O_5/ha and 50 kg N + 25 kg P_2O_5/ha at harvest. The beneficial increase in number of grains and its weight/plant and 1000 grain weight was recorded with increased levels of fertilizers.

The application of 75 kg N + 37.5 kg P_2O_5/ha and 100 kg N + 50 kg P_2O_5/ha were on par but increased grain and bhusa yield significantly over 25 kg N + 12.5 kg P_2O_5/ha and 50 kg N + 25 kg P_2O_5/ha. The maximum additional net returns of Rs.2466/ha with benefit cost ratio of 5.57 were obtained due to application of 75 kg N + 37.5 kg P_2O_5/ha. It is, therefore, advisible to fertilize irrigated safflower with 75 kg N + 37.5 kg P_2O_5/ha.

The nitrogen and phosphorus content in grain and bhusa and uptake of these nutrients increased progressively with increased levels of fertilizers. The oil content in grain was decreased whereas protein content was increased with increased levels of fertilizers.

The increased plant densities produced greater plant height, whereas, plant spread and number of main and sub-branches and dry matter accumulation were increased with decreased plant densities. The number of capsules, number of grains and its weight/plant and 1000 grain weight showed beneficial improvement with decreased levels of plant densities.

The grain and bhusa yields were significantly increased with increased levels of plant densities. Therefore, the plant density of 2.25 lakh plants/ha would be considered optimum for irrigated safflower.

The nitrogen and phosphorus content in grain and bhusa and uptake of these nutrients and total uptake was increased progressively with increased levels of plant densities. The oil and protein content in grain were declined slightly with decreased levels of plant densities.

Pages.

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1. INTRODUCTION

1. INTRODUCTION

Safflower (Carthamus tinctorius L.) is an important rabi oil seed crop not only in India but also all over the world. In India, it is grown in the States of Maharashtra, Gujrat, Madhya Pradesh and Karnataka.

In India, the total area under this crop is 7,60,000 hectares and annual production is 4,23,000 tonnes with the average productivity of 557 kg per hectare. Maharashtra stands first in area and production amongst the different States in India. The crop is grown in scarcity and assured rainfall zone comprising the districts of Aurangabad, Ahmednagar, Solapur, Osmanabad, Pune, Nanded, Parbhani and Jalna.

Safflower has been recognised as a crop of economic importance. The importance of safflower oil lies in its low content of polyun-saturated fatty acid and is, therefore, considered more suitable for human consumption, particularly for heart patients. Safflower is grown mainly for its oil which is highly regarded as a cooking medium. It is used in paints, varnishes, due to its quick drying property. It is used as a dye and also used for culinary and illuminating purpose and in making soap. A geletinous 'Roughon' is used in glass, cement and can be substituted for plaster of Paris for fixing tiles and stones for decoration. It is also used for the manufacturing of water proof clothes. After the seed is crushed for oil, the meal makes an excellent protein

Concentrate feed for livestock. Besides these uses, safflower cake is utilised as an organic manure.

The consumption of oil in India per capita per annum is very little i.e. only 3 kg; as compared to the 25 kg per capita per annum in the foreign countries. As per recommendations of scientific council of India, our need is 11 kg per capita per annum. From this, it is clear that our consumption is less than that of other countries because of comparatively low production of edible oil and its high prices.

Safflower does best in dry climate but its yield could be enhanced under irrigated conditions.

The cultivation of safflower in Maharashtra is confined to be taken as a mixed crop in jowar and wheat, under rainfed conditions. It is often used as a protective crop around the border of the main crop. Safflower is xerophytic plant and is very hardy. The roots go deep into the soil up to 120-135 cm and make better utilization of the nutrient and moisture from the deeper soil layers.

Safflower being a drought resistant crop and tolerate the adverse climatic conditions and due to a present oil shortage, it has better chances to grow as an important oilseed crop in Maharashtra. However, the average yield of safflower in Maharashtra is very low (557 kg/ha). Probable reasons for the low yield of safflower are the lack of high yielding varieties, utilisation of most neglected soils, poor agronomic management, lack of fertilizer use, lack of irrigation facilities and plant protection measures.

With the introduction of major, medium and minor irrigation projects and expansion of existing projects, there is tremendous scope for introduction of safflower as dry-cum wet crop. However, it is observed that the research information on irrigated safflower is limited. Therefore, it is felt necessary to suggest suitable agronomic management practices for boosting the yield of irrigated safflower. It is an established fact that safflower responds well to fertilizer application under optimum soil moisture conditions and, if adjusted properly with irrigation at critical growth stages. Limited information available has indicated that irrigation water increased the yield of safflower more in presence of nitrogen than its absence (Jones and Tucker, 1968). The response of safflower to nitrogen application depends upon moisture supply. Singh and Yusuf (1981) reported that under restricated moisture supply the higher dose of nitrogen was not effective but when combined with an adequate supply the yield was increased substantially.

The present practice being however, that farmers does not apply any kind of fertilizers for safflower and hence the yield levels are low. Therefore, it becomes essential that a suitable fertilizer dose is worked out to maximise the production of this important oilseed crop.

The yield of a crop is largely a function of two important factors viz., plant density per unit area and the yield per plant. Khuspe and Saoji (1968) reported that grain yield was the highest where row spacing of 45 cm was maintained as compared to spacings of 30 and 60 cm. Montilla (1968) reported that plant spacing under minimum irrigation had no effect on total plant yield. However, under normal irrigation, it was increased with increase in number of plants.

The findings of the earlier workers on optimum row spacing that plant densities varies according to the climatic conditions and type of the soil of the particular location. Information regarding the interaction effects of nitrogen and phosphate fertilization and plant density on growth and yield of safflower particularly under irrigated conditions is also limited. Therefore, the present investigation was conducted at the Agricultural College Farm, Pune, with the following objectives.

(1) To find out the suitable nitrogen and phosphorus level of fertilizers for safflower under irrigated conditions.

(2) To find out suitable level of plant density for safflower under irrigated conditions.

(3) To study the interaction effects between nitrogen and phosphorus fertilization and plant densities.

(4) To study the uptake of nutrients by safflower in relation to nitrogen and phosphorus fertilization and plant densities.

2. REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1 Effect of nitrogen on the growth components of safflower..

Dhote and Ballal (1964) studied the effect of N, P and K on growth components of safflower in pot culture at Pune. They reported that though there was no significant variationin height of plant, number of flowers and capsules per plant due to fertilizer treatment, the application of nitrogen increased number of branches per plant.

Jones (1966) observed that the number of heads per plant and number of seeds per head in tertiary heads, and grain size in secondary heads were increased with the increase in the doses of nitrogen.

Gilbert and Tucker (1967) studied the effect of source, rate and time of application of nitrogen on irrigated safflower and found that plant height was influenced significantly by the levels of nitrogen, but the differences due to source were not significant.

Jones and Tucker (1968) showed that the nitrogen application increased the number of heads, number of seeds per head in tertiary heads, seed weight in secondary head and head weight in secondary and tertiary position.

Sheelavantar (1973) at Dharwar, reported that dry matter production and its distribution into plant parts increased by nitrogen application upto 40 kg/ha and reduced thereafter.

Girase et al. (1976) studied the response of safflower to fertilizer application at Jalgaon under rainfed conditions and revealed that the plant height, number of primary and secondary branches per plant and spread of plant increased significantly with the increase in the dose of nitrogen upto 40 kg/ha.

Mane (1976) reported beneficial increase in height due to nitrogen application. The other characters viz., spread, number of main branches and subbranches were increased significantly with each increase in nitrogen dose upto 100 kg/ha during good seasonal conditions. The plant height of safflower was significantly increased due to application of 150 kg N/ha (Nasar et al. 1978).

Bhan et al. (1980) reported that under rainfed conditions of Kanpur plant height and number of branches per plant were significantly increased by nitrogen application but delayed crop maturity.

Girase et al. (1980) revealed that though the plant height was not influenced significantly by nitrogen levels the spread and number of primary branches were significantly influenced by nitrogen levels. Eweida et al. (1981) at Nubaria (Egypt) studied the influence of some nutrient elements on the plant characters, seed yield and quality of safflower and concluded that the plant height was not affected by cultivar or trace elements. The maximum plant height (111-112 cm) was recorded with 142 kg N/ha (60 kg N/Feddan).

Umrani et al. (1981) studied the response of safflower to application of nitrogen under rainfed conditions at Solapur and reported that the plant height was significantly increased at 25 kg N/ha in one season, while in next seasons plant height was increased significantly by 50 kg N/ha over control. As regards primary branches, application of 50 kg N/ha showed better performance.

The effect of spacing and fertilizer application on the growth components of safflower (N-62-8) was studied at Dhule by Mane and Narkhede (1982b) and they reported that the plant height was not influenced by nitrogen levels, but plant spread differed significantly by different levels of nitrogen over control. They have further reported that the main and sub-branches per plant were significantly influenced by the different levels of nitrogen.

Mulik (1984) reported that application of 25 kg N/ha increased plant height upto 90 days of crop growth after that application of 75 kg N/ha produced maximum height of plant. After 105 days onwards, the application of 50 kg N/ha produced maximum spread of the plant. The number of primary and secondary branches were maximum due to 75 kg N/ha. The maximum dry matter accumulation was due to application of 75 kg N/ha. The application of higher doses of nitrogen delayed the initiation of flowering and prolonged the maturity. In general, safflower plant responds well to nitrogen application from 25 kg to 150 kg N/ha.

2.2 Effect of nitrogen on yield contributing characters, grain and oil yield of safflower.

Gilbert and Tucker (1967) studied the effect of source, rate and time of application of nitrogen on the yield of safflower at Mesa, Arizon and found that the magnitude of nitrogen response increased for each additional dose of 50 lb., however, this increased response was only upto 150 lb/acre. Further increase occurred when it was applied in split dose, viz., half dose was applied at planting and half at the spring.

Sheelavantar (1973) revealed that under rainfed conditions, application of 40 kg N/ha recorded the highest yield of 20.02 and 16.20 q/ha and oil yield of 5.22 and 5.41 q/ha during 1971 and 1972, respectively.

Tavora (1973) observed that applied N generally promoted the seed production but reduced the oil content of seed from tertiary heads.

The safflower crop was found to respond significantly to increase in levels of nitrogen at Jalgaon. The levels of nitrogen were 25, 50 and 75 kg N/ha (Anonymous, 1976).

Mane (1976) showed the beneficial effects of nitrogen application on number of capsules per plant and 1000 grain weight, number of grains per capsule and grain weight per plant in both seasons. Maximum grain and straw yield were at 100 kg N/ha. The oil and protein content of grain was also found to increase with increase in the level of nitrogen upto 100 kg N/ha.

Chaudhari (1977) observed that the application of 25 kg N/ha increased the grain yield significantly over control. However, he further reported that the increase in nitrogen did not raise the yield significantly.

Sounda et al. (1977) at Delhi reported that nitrogen application increased the number of heads per plant, the grain number per head and test weight; however, the magnitude of increment was higher between 0 to 60 kg N/ha than between 60 to 120 kg N/ha.

Nasar et al. (1978) at Beirut (Lebamon) opined that nitrogen application at 75 kg N/ha was necessary for higher seed, oil and protein yield as compared to control; however, the further increase in the dose upto 150 kg N/ha or more gave no additional yield, but significantly increased the number of heads/plant. The seed weight and the number of seed per head were not affected.

Arunachalam and Morachan (1979) at Coimbatore, revealed that there was no response to nitrogen application upto 40 kg/ha which gave maximum seed yield of 11.60 q/ha. The next best level of N was 20 kg/ha (10.3 q/ha).

Singh and Singh (1980) studied the effect of graded levels of moisture regimes, N and P fertilization on seed yield at Kota, and reported that the seed yield with the application of 120 kg N/ha was the highest and significantly more than 80 kg and 40 kg N/ha. However, the oil was significantly affected by nitrogen levels recording the highest oil production to the tune of 5.69 kg/ha per day with 120 kg N/ha.

Umrani _et al_. (1981) at Solapur showed that a significant change was noticed as regards the number of capsules due to nitrogen application. They further reported that the maximum response of 15.8 kg grain/kg N applied was noticed at 25 kg N/ha. However, there was significant increase in grain yield of safflower even at 75 kg N/ha under rainfed conditions.

The number of capsules/plant, the test weight, the number of grains per capsule and the grain weight/plant was favourably influenced by the nitrogen fertilization at Dhule by Mane and Narkhede in 1982. They further reported that grain yield was found to increase with the increase in the level of nitrogen. The application of 100 kg N/ha increased the grain yield significantly over control.

Sharma and Verma (1982) observed significant increase in effective heads per plant, number of seeds per head, seed yield per plant and test weight by increasing the levels of nitrogen. They further reported that the seed yield was significantly influenced with nitrogen fertilization. Application of 60 kg N/ha resulted in the highest production of grain as compared to other levels.

Mulik (1984) observed that the application of 75 kg N/ha produced maximum number of capsules per plant, maximum number of grains per plant and higher test weight. Similar trend was observed in respect of the grain weight per plant. The grain and bhusa yield was significantly more (19.51 q/ha) with the application of 75 kg N/ha. There was increase in the protein content with the increase in the levels of nitrogen.

2.3 Effect of phosphorus on growth components of safflower.

Girase *et al.* (1976) studied the response of safflower to phosphorus application under rainfed conditions at Jalgaon and reported that plant height was not influenced significantly.

The effect of spacing and fertilizer application on growth components of safflower was studied at Dhule by Mane and Narkhede (1982) and reported that phosphate fertilization did not show beneficial effect on the growth components of safflower.

2.4 Effect of phosphorus on yield contributing characters, grain and oil yield of safflower.

Werkhoven and Massantini (1967) reported that band placement of P was more efficient than broadcasting. It has been observed from a fertilizer experiment with N (0, 22.4 kg/ha) and P_2O_5(0, 22.4 kg/ha) at Badnapur and Niphad (Anonymous, 1971) that phosphorus fertilization had no effect on increasing the yield and oil content of seed. Kamel and Mohamed (1973) studied the effect of different levels of N, P, K fertilization on the physical and bio-chemical properties of safflower oil and reported that the application of phosphorus increased the seed oil content.

Girase et al. (1976) at Jalgaon reported that the number of capitula per plant and grain yield of safflower was not influenced significantly by the levels of phosphorus probably because the applied phosphorus got fixed in black soils. Similar findings were reported at Akola by Chaudhari (1977).

Singh and Singh (1980) at Kota (Rajasthan) reported that the application of phosphorus at 40 kg/ha produced significantly higher yield over 20 kg/ha and control.

Mane and Narkhede (1982b) at Dhule reported that there was no significant response on the yield components and grain yield due to phosphorus application. Sharma and Verma (1982) at Agra revealed that a dose of 40 kg P_2O_5/ha appeared beneficial for the crop. The higher dose of 80 kg P_2O_5/ha declined yield.

2.5 Effect of nitrogen and phosphorus on the growth components of safflower.

Dhote and Ballal (1964) at Pune reported that there was no significant variation in the height of plant and the number of flowers per plant due to fertilizers. It was, however, observed that the application of nitrogen increased substantially the branching per plant though it did not increase the number of flowers.

Hoag et al. (1968) at Minot, North Dakota, studied the effect of N, P and K treatment combination and row spacing on yield, quality and physiological response and observed that the application of fertilizer has significantly advanced growth and increased the plant height.

Ramanath et al. (1974) studied the response of fertilizer under dryland conditions at Bellary (Karnataka) and reported that plant height did not differ significantly due to nitrogen and phosphorus fertilization.

2.6 Effect of nitrogen and phosphorus on yield components, yield and oil content of safflower.

Dhote and Ballal (1964) studied the effects of N, P and K on the growth and composition of safflower at Pune and reported that there was no significant variation in capsules per plant and weight of capsules due to the fertilizers.

While studying the effect of N, P and K fertilizer and row spacing on yield and quality of safflower, Hoag et al. (1968) observed that the application of fertilizers significantly increased the number of heads per plant, seed weight per plant and yield.

Quilantan (1969) conducted four trials with N, P and K on safflower and observed that N, P and K increased the safflower yield.

The fertilizer trials on N, P and K combinations were conducted on safflower at Niphad and Badnapur (Maharashtra) on N-62-8 safflower variety and found that nteither N, P, K nor their combinations had any effect on increasing the grain yield as well as the oil content of seed (Anonymous, 1971).

Kamel and Mohamed (1973) studied the effect of different rates of N, P, K combinations on the protein and oil content of safflower and concluded that the increase in the rates of nitrogen reduced the seed oil contents whereas P and K combinations increased it. The test weight was not affected by different rates of fertilizers.

Ramnath et al. (1974) at Bellary reported that the number of capsules per plant did not differ significantly due to different levels of nitrogen and phosphorus. They further reported that the application of 20 kg N + 20 kg P_2O_5/ha increased the yields of five safflower cultivars from 341 kg/ha (control) to 362 kg/ha.

Rahman and Chakravarty (1978) reported that the seed yield of safflower increased with the increase in the application of N, P, K fertilizers to maximum with 45 kg N + 34 kg P_2O_5+ 34 kg K_2O/ha. The highest oil content was obtained by the application of 45 kg N + 45 kg P_2O_5+ 45 kg K_2O/ha.

The response of safflower to nitrogen and phosphorus was studied at Annigeri by Veeranna and Channappa (1981) and they reported that the application of 45 kg each of N and P per hectare, with a common dose of 20 kg potash per hectare would be ideal to get economical yield of safflower under dryland condition.

2.7 Effect of plant density on the growth components of safflower.

Gilbert and Tucker (1967) observed a strong co-relation between yield and number of heads per plant. They also reported that the number of seed per head was affected to a minor degree but significant differences in seed weight did not occur.

Montilla (1968) studied the different spacings and reported that the plant height was affected by inter-row and intra-row spacings.

While studying the nitrogen levels and spacing in irrigated safflower, Kulandaivelu et al. (1974) at Coimbatore reported that plant height remained unaffected by different spacings. They further reported that the wider spacing increased the number of branches but has not reflected on the yield.

Nasar *et al.* (1978) at Beirut, Lebanon, reported that the increasing population rates from 1,33,333 to 2,66,667 and even at 5,33,333 plants/ha increased the plant height. Similarly, the response of safflower varieties to plant densities and nitrogen levels was studied at Jalgaon by Girase *tet al.* (1980) who reported that the plant height was significantly affected by plant densities over 55 and 98 thousand per hectare. The lower plant density of 55,000 plants/ha recorded the highest spread, number of primary and secondary branches per plant; however, these were reduced significantly with increasing plant density.

Mane and Narkhede (1982) reported that by increasing the row to row and plant to plant spacings, the height, spread and the main and sub-branches/plant were increased favourably.

Mulik (1984) studied that by maintaining population of 0.74 lakh plants per hectare produced maximum number of primary (14.29) and secondary (22.77) branches which were subsequently reduced with increasing the plant population.

2.8 Effect of plant density on yield components, yield and oil content of safflower.

Brauns (1961) at Biloela, reported that good yields of safflower can be obtained from 14-in (35 cm) row spacing using 14-27 lb seed/acre (15.9 - 30.7 kg/ha) and from 21-in (52 cm) row spacing and using about 18 lb seed/acre (20.5 kg/ ha); however, 7-in and 28-in (17.5 and 70 cm) spacing gave poor yield.

Beech and Norman (1966) studied on varying plant densities from 25,000 to 593,000 plants/acre (62,5000 to 14,82,500 plants/ha) at Kunnunurra, West Australia and reported that number of heads/plant decreased with increased plant density, while 100 seed weight and number of seeds/head had a very little effect. Primary heads gave the greatest number and weight of seed, while the tertiary heads had the highest oil content. They observed that seed yield increased upto 1,14,000 plants/acre then declined sharply with higher densities.

Montilla (1968) studied the influence of inter-row and intra-row spacing on yield and height of safflower. Safflower Gilla was sown at inter-row spacing of 40, 60 or 80 cm and intra-row spacing of 5, 10 or 15 cm. The highest yield of 1450 kg seed/ha was obtained from the highest plant density of 50,0000 plants i.e. with 40 x 5 cm spacing.

Hoag et al. (1969) while studying the effect of fertilizer treatment and row spacing found that significantly higher yields of grain resulted from the close (15 cm) and medium (53 cm) spacing than the wider (91 cm) spacing. Close spacing also resulted in significantly higher oil content.

Mundel (1969) conducted a trial with 30 x 7.5, 60 x 7.5, 45 x 30 and 75 x 30 cm spacings on safflower and recommended that 45 cm spacing between rows may be the most useful for rainfed conditions. Tiwari and Mandio (1972) found that 45 x 5 cm spacing gave higher yield (1.53 t/ha) than 45 x 10 and 45 x 15 cm spacings.

At Coimbatore, nitrogen cum spacing experiment on irrigated safflower was conducted by Kulandaivelu et al. (1974) which obtained the highest seed yield with 60 x 15 cm spacing (787 kg/ha) than 60 x 22.5 cm (758 kg/ha) and 60 x 30 cm (632 kg/ha).

A trial with four (30, 45, 60 and 75 cm) inter-row spacings and five (15, 22.5, 30, 37.5 and 45 cm) intra-row spacings at Jalgaon was conducted for 3 years on safflower C. N-62-8. It was observed that the yield differences due to inter and intra row spacings were significant during only one season of the three. Pooled results indicated that the highest yield was given by 75 cm spacing between row and that the differences in yield due to plant to plant spacings were non-significant (Anonymous, 1975). Further they have observed significant reduction in yield with the reduction in plant population from 1,48,000 to 74,000 plants/ha. El-Shamma et al. (1975) at Abus-Ghraib (Iraq) studied the different row spacings and found that the highest grain yield and oil content was obtained with a 50 cm row spacing than 30, 40 or 60 cm spacings.

Abel (1976) reported that number of seeds per head and seed weight were affected by larger plant population so the yields were practically equal in 2,58,328 and 4,30,547 plants/ha with the single row and the two row plots, respectively atMesa, Ariz. An inter-row spacing of 22.5 cm produced the maximum yield of safflower sown on 15th October with 68 kg N/ha (Khan and Meman, 1976).

Sounda et al. (1977) at Delhi studied the levels of nitrogen and plant population and concluded that with increase in plant population, the number of heads/plant, grain number/ head and 1000 grain weight, decreased. However, significant decrease was only observed between 50,000 to 1,00,000 plants/ha

While studying the N fertilization and population rate at Beirut, Lebanon, Nasar et al. (1978) reported that increasing the population rate from 1,33,333 to 2,66,667 (10 x 75, 5 x 75, 10 x 37.5 and 5 x 37.5 cm) and even upto 5,33,333 plants per hectare increased seed, oil and protein yield, however, the number of seeds/head were reduced and seed weight oil percentage were not affected. They further reported that 37.5 cm row spacing gave better yields than 75 cm. Response to 5 cm within row spacing as compared to the 10 cm was absent.

Bhan et al. (1980) at Kanpur reported that the wider row spacing of 60 cm exhibited better effect on the yield components, over the narrow spacing of 45 cm, in 1974-75 but found at par in 1975-76.

Girase *et al.* (1980) at Jalgaon reported that the population of 55,000 plants/ha recorded the highest number of capitula per plant and the same were reduced significantly with increased plant densities.

The total number of heads per plant, the number of grain per head and the grain yield per plant increased significantly with the increase in row as well as plant spacings at Agra. The highest grain yield of 22.4 q/ha was obtained with 45 cm inter-row spacing and 29.0 q/ha with 10 cm intra-row spacing (Ahuja, 1981).

Singh and Yusuf (1981) at Jodhpur reported that the rate of increase in yields of safflower was higher with the increase in N levels at the narrower (20 cm) row spacing than at the wider (60 cm) spacing. Kamel *et al.* (1982) has studied different N levels, inter and intra-row spacings and revealed that the highest seed and oil yields were obtained from the narrowest row and hill spacings with the highest nitrogen levels.

Mane and Narkhede (1982a) at Dhule reported that the number of capsules/plant, grain weight/plant and the number of grains per capsule increased with the increase in plant to plant spacings; however, the test weight and grain yield were adversely affected due to increase in plant to plant spacings.

2.9 Uptake of nitrogen, phosphorus and potash by safflower

Dhote and Ballal (1964) studied the effect of different levels of N, P and K on composition and uptake of nutrients by safflower in pot culture and reported that the application of N and P increased the nitrogen percentage in seed but not in straw. They further reported that the nitrogen applied was better utilized if it was combined with phosphorus. The application of phosphorus, either alone or in combination with nitrogen increased P content substantially of seed. The potash did not show any beneficial effect. The placement of phosphorus and nitrogen had no effect on the total phosphorus concentration in the plant (Werkhoven and Massantini, 1967).

Jones and Tucker (1968) stated that the total nitrogen in the above ground plant portions increased with the increase in the levels of nitrogen, doubling from the first bloom to maturity. Similarly, the uptake of N, P and K at harvest was significantly affected by the moisture regimes, levels of nitrogenand phosphorus (Singh and Singh, 1980).

Haby et al. (1982) reported that increasing the rates of N fertilizer significantly increased the N and K concentration but reduced P content in the straw; however, potassium fertilizer had no effect on N, P and K content of safflower.

Mulik (1984) reported that the uptake of nitrogen by grain increased with the increase in the levels of nitrogen. The highest uptake of 52.91 kg/ha was observed with 75 kg N/ha highest level tried.

3. MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation on safflower (*Carthamus tinctorius* L.) was carried out to find out a suitable combination of fertilizer level and plant density. The field experiment was carried out during *rabi*, 1985-86. The details of materials used and methods adopted during the period of investigation are given in succeeding paragraphs.

3.1 Materials

3.1.1 Experimental site

The field experiment was laid out on plot No.642 of 'F' Division of the Agricultural College Farm, Pune-411 005. The experimental field was uniform in soil depth upto 90 cm and fairly levelled for irrigation application.

3.1.2 Soil

The soil samples upto 0-30 cm depth from 5 different locations of the experimental field were collected before the start of experiment and a composite sample was prepared and analysed for physico-chemical properties of the soil.

The data regarding physico-chemical properties of experimental soil are present in Table 1.

Table 1 : Physico-chemical composition of the experimental soil

Sr. No.	Soil properties	Compposition per cent 0.30 cm	Method used
A)	**Physical properties**		
1.	Coarse sand	7.54	International pipette method (Piper, 1966).
2.	Fine sand	10.29	
3.	Silt	10.55	
4.	Clay	60.03	
5.	Organic matter	1.26	
6.	Textural class	Clayey	
B)	**Chemical properties**		
1.	Organic carbon	0.75	Walkaley and Black Rapid Filtration method (Piper, 1966).
2.	Available nitrogen (kg/ha)	188.19	Modified Kjeldahl's method (A.O.A.C.,1965).
3.	Available P_2O_5 (kg/ha)	21.98	Modified Olsen's method (Olsen, 1954).
4.	Available K_2O (kg/ha)	480.23	Flame photometer Method (Hanway and Heidal,1967).
5.	pH soil : Water (1:2:5)	8.2	Glass Electrode Method (Piper, 1966).
6.	Electrical conductivity (mm hos/cm)		

The chemical composition according to the criteria laid by Muhr et al. (1965), the experimental soil was low in available nitrogen, medium in available phosphorus and rich in available potash. The soil was slightly alkaline in reaction. The soil under experimental field was clayey in texture.

3.1.3 Climatic condition and location :

Agro-climatically Pune is situated in the sub-tropical region on the North latitude 18°-22' and 73°-51', East longitude at an altitude of 559 meters above the mean sea level. The annual average precipitation is about 730 mm and is mostly received in 48 rainy days. It receives mostly from South-west manson, commencing from about middle of June. Of the total annual precipitation, about 75 per cent precipitation is received during the period from June to September, while the remaining quantity is received mostly in months of October and November. From the month of December onwards upto harvest of rabi and summer crops, there are practically no rains.

In order to get an idea about the climatic conditions prevailing during the period of present investigation i.e. from October, 1985 to March, 1986, the data on weather parameters were obtained from the Meteorological Observatory situated at the Agricultural College Farm, Pune-5. The relevant data are presented in Table 2.

Table 2 : Meteorological data during cropping period from last week of October, 1985 to 1st week of March, 1986 at Agronomy Farm, Pune-5.

Month	Week No.	Temperature °C		Humidity		Rain-fall mm.	No.of rainy days
		Maximum	Minimum	Morning 7-30	Evening 14-30		
October 1985	43	31.8	11.7	91	30	-	-
November 1985	44	30.9	10.7	82	24	-	-
	45	30.9	15.7	85	40	110.4	3
	46	29.9	10.8	87	26	-	-
	47	30.7	10.7	88	27	-	-
	48	29.5	11.2	90	41	-	-
December 1985	49	29.3	10.1	90	40	-	-
	50	30.1	14.2	89	47	-	-
	51	29.6	12.6	89	42	-	-
	52	32.0	10.5	88	34	-	-
January 1986	1	29.3	8.6	81	30	-	-
	2	28.9	12.3	89	39	-	-
	3	28.1	12.1	93	38	-	-
	4	30.5	12.7	88	31.	-	-
	5	30.2	11.2	89	31	-	-
February 1986	6	31.3	12.4	86	30	-	-
	7	30.5	10.4	87	24	-	-
	9	33.2	14.9	69	22	-	-
March 86	10	35.0	16.2	75	20	-	-

The total rainfall of 110.4 mm during three rainy days was received during life period of crop. The mean maximum and minimum temperatures recorded during crop period were 35°C and 8.6°C, respectively. The mean relative humidity during the crop growth period ranged from 75 to 93 and 20 to 47 per cent during morning and evening hours, respectively. Thus, the climatic conditions were favourable for the safflower crop.

3.1.4 Cropping history of the experimental plot for the last three years is presented in Table 3.

Table 3 : Cropping history of the experimental plot:

Year	Season	Crop grown	Fertilizers and manures (applied (kg/ha)		
			N	P_2O_5	K_2O
1983-84	Kharif	Cotton	100	50	50
	Rabi	Wheat	100	50	50
1984-85	Kharif	Cowpea	25	50	0
	Rabi	Fallow	-	-	-
	Summer	Groundnut (experiment)	As per treatments		
1985-86	Kharif	Jowar	120	60	60
	Rabi	Present investigation			

3.1.5 Safflower (Bhima) :

The safflower variety Bhima (S-4) evolved at the Dry Farming Research Station, Solapur was released for general cultivation during 1982-83. It is drought resistant, the roots grow deep upto 120-135 cm and make better utilization of nutrients and moisture. It matures in 135-140 days. The oil percentage is 30-31 per cent. The yield is about 18-20 q/ha. It is recommended for Maharashtra and Karnataka under both rainfed as well as irrigated conditions.

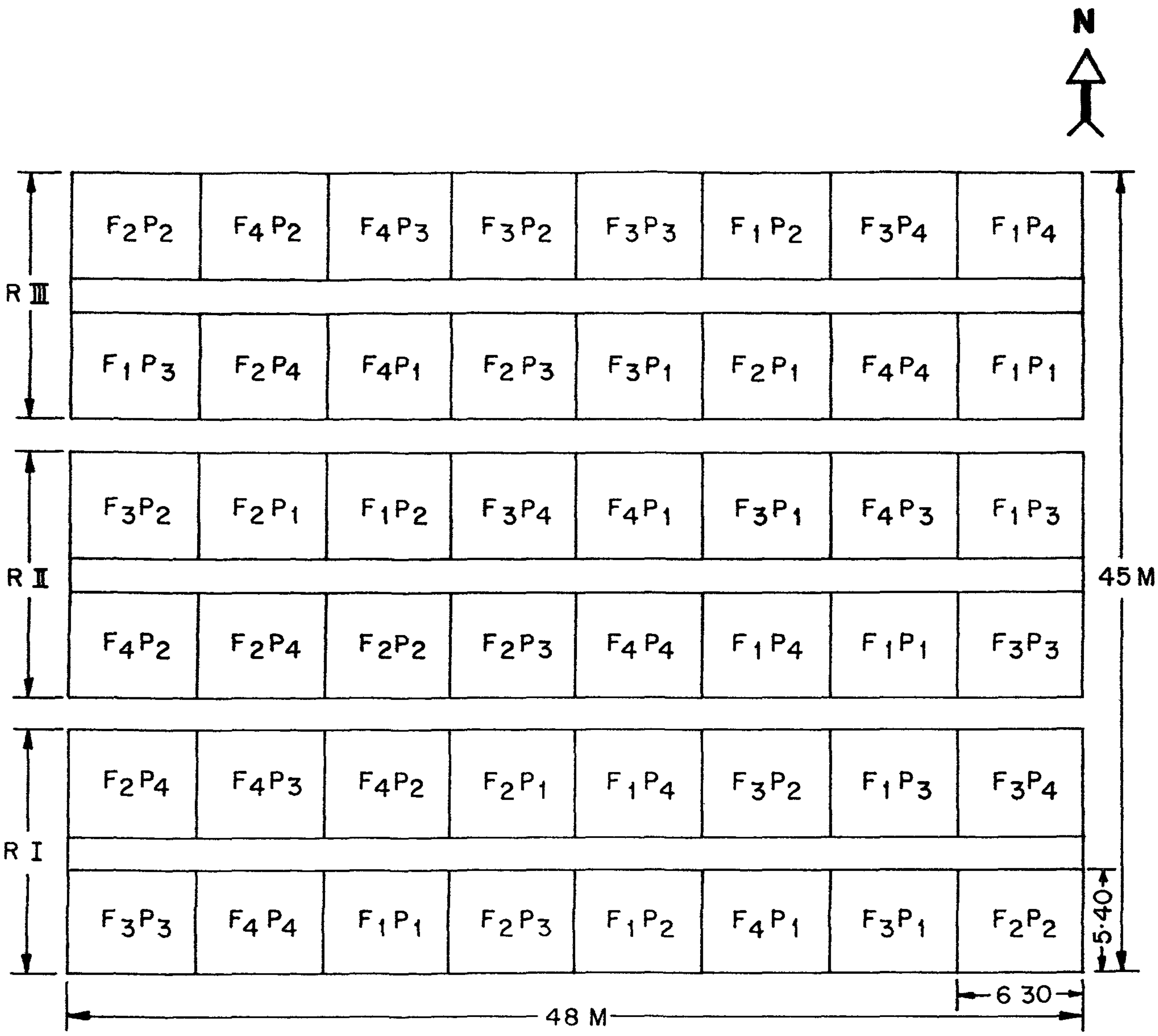
3.2 Metnods :

3.2.1 Experimental Details :

The experiment was laid out in a factorial randomised block design. There were four fertilizer levels and four plant densities forming 16 treatments combinations which were replicated three times. The details of treatments along with symbols used are given in Table 4.

Table 4 : Details of treatments and symbols used in the experiment:

Treatment details		Symbols
Fertilizer levels		
1. 25 kg N + 12.5 kg P_2O_5/ha	...	F_1
2. 50 kg N + 25 kg P_2O_5/ha	...	F_2
3. 75 kg N + 37.5 kg P_2O_5/ha	...	F_3
4. 100 kg N + 50 kg P_2O_5/ha	...	F_4



Fertilizer Levels	Plant Densities
F_1 = 25 KgN + 12 5 kg P_2O_5/ha	P_1 = 2 25 lakh plants / ha (45 x 10 cm)
F_2 = 50 KgN + 25 kg P_2O_5/ha	P_2 = 1 50 lakh plants / ha (45 x 15 cm)
F_3 = 75 KgN + 37·5 kg P_2O_5/ha	P_3 = 1·00 lakh plants / ha (45 x 22·5 cm)
F_4 = 100 KgN + 50 kg P_2O_5/ha	P_4 = 0·75 lakh plants / ha (45 x 30 cm)

Design – Factorial R. B. D.

Plot size – Gross – 6 30 x 5 40 M^2 , Net – 5 40 x 4 50 M^2

Fig. 1 : Plan of layout .

Table 4 (contd.)

Treatment details	Symbols
<u>Plant densities</u>	
1. 2.25 lakh plants/ha (45x10 cm) ..	P_1
2. 1.50 lakh plants/ha (45x15 cm) ..	P_2
3. 1.00 lakh plants/ha (45 x 22.5 cm)	P_3
4. 0.75 lakh plants/ha (45 x 30 cm)	P_4

The other details of the experiment are as follows :

(a) Total number of plots ... 48

(b) Plot size : Gross - 6.30 x 5.40 M^2

Net - 5.40 x 4.50 M^2

(c) Method of sowing : Dibbling

(d) Date of sowing : 31-10-1985.

The plan of lay out of the experiment is depicted in Fig.1. The allocation of treatments to the respective plot was done at random.

3.2.2 Fertilizer application :

Urea containing 46.00 per cent nitrogen and single super phosphate containing 16.0 per cent P_2O_5 was applied as per the treatments, before sowing as a basal dose.

3.2.3 Field operations :

The details of the various cultural operations carried out in the experimental plot during the <u>rabi</u> season of 1985-86 are presented in Table 5.

<u>Table 5</u> : Schedule of cultural operations and other operations:

Sr.No.	Name of the operation	Date of operation
A)	Preparatory tillage	
1.	Ploughing	17-10-85
2.	Harrowing	28-10-85
3.	Layout	29-10-85
4.	Preparation of flat beds and water channels ...	29-10-85
B)	Fertilizer applications	
1.	Application of urea and single superphosphate as per treatments ...	30-10-85
C)	Sowing	
1.	Sowing of seeds by dibbling	31-10-85
D)	Post sowing operations	
1.	Gap filling	15-11-85
2.	Thinning	25-11-85
3.	Hoeing	30-11-85
4.	Weeding	3-12-85
E)	Irrigation	
1.	First irrigation ...	1-11-85
2.	Second irrigation ...	16-11-85

Table 5 (contd.)

Sr.No.	Name of the operation		Date of operation
	3. Third irrigation	...	9-12-85
	4. Fourth irrigation	...	22-1-86
F)	Plant protection measures		
	1. Endosulphan spraying	...	6-12-85
	2. Endosulphan spraying	...	16-12-85
	3. Endosulphan spraying	...	19-12-85
	4. Endosulphan spraying	...	26-12-85
	5. BHC 10% dusting	...	7-1-86
	6. BHC 10% dusting	...	15-1-86
G)	Harvesting ...	...	3-3-1986
H)	Threshing and cleaning	...	20-3-86

3.2.3.1 Sowing :

The crop was sown on 31st October, 1985 by dibbling 2-3 seeds/hill with a spacing of 45 cm between rows. The intra-row spacing were kept as per the treatments.

3.2.3.2 Gap filling and thinning :

Gap filling was done 15 days after the sowing. Thinning was carried out after 25 days after sowing, keeping a single plant at each dibole.

3.2.3.3 Hoeing and hand weeding :

Hoeing was carried out 30 days after sowing. The weeding operation was carried out 33 days after sowing.

3.2.3.4 Irrigation :

The first irrigation was given after sowing and the second, third and fourth irrigation were given at 15, 39 and 83 days after the sowing, respectively.

3.2.3.5 Plant protection measures :

In order to protect the experimental crop from the semiloopers and aphids, control measures with endosulphan spray and 10 per cent BHC dusting were adopted.

3.2.4 Biometric observations :

3.2.4.1 Sampling technique :

For various observations on the growth characters five plants from net plot were selected randomly. These plants were suitably labelled and all biometric observations were recorded on these plants at an interval of 15 days from 30 days after sowing.

3.2.4.2 Growth studies :

The schedule of biometric observations recorded during the course of investigation is presented in Table 6.

Table 6 : Schedule of biometric observations on different growth characters of safflower:

Sr. No.	Name of the observation	Size of the sample	Observations recorded on days from sowing	Frequency
1	2	3	4	5
A)	Plant population	Net plot	After thinning and at harvest	2
B)	Growth studies			
	1. Plant height	5 plants	30, 45, 60, 75, 90, 105 and at harvest	7
	2. Plant spread	5 plants	30, 45, 60, 75, 90, 105 and at harvest	7
	3. Number of branches/plant	5 plants	60, 75, 90, 105 and at harvest	5
	4. Total dry matter/plant	1 plant	30, 45, 60, 75, 90, 105 and at harvest	7
C)	Development studies			
	1. Days to 50 per cent flowering	Net plot	-	1
D)	Yield contributing characters			
	1. Number of capsules/plant	5 plants	90, 105 and at harvest	3
	2. Number of grains/plant	5 plants	At harvest	1
	3. Weight of grains/plant	5 plants	At harvest	1
	4. Thousand grain weight	Net plot	At harvest	1

Table 6 (contd.)

1	2	3	4	5
E)	Post harvest studies			
	1. Grain yield (q/ha)	Net plot	At harvest	1
	2. Bhusa yield (q/ha)	Net plot	At harvest	1
	3. Harvest index	-	At harvest	-
F)	Chemical studies			
	1. Nitrogen content in plant and seed (per cent)	-	At harvest	-
	2. Phosphorus content in plant and seed (per cent)	-	At harvest	-
	3. Oil and protein content in grain (per cent)	-	At harvest	-

A) Pre-harvest studies :

1. Plant population count :

The initial plant count was recorded after thinning while the final plant count was recorded just before the harvest of the crop.

2. Plant height :

The plant height was measured from the ground level to the tip of bud on the main branch till flowering and thereafter upto the base of capsule.

3. Plant spread :

The plant spread gives the vigour of plant. It was recorded in both the directions i.e. East-West and North-South on the same date on which the height was recorded.

4. Number of branches per plant :

The number of main and sub-branches per plant was recorded on the same date on which the height and spread was taken.

5. Total dry matter :

For the determination of the total dry matter per plant and its subsequent development, a plant other than the observatinnal plant was selected randomly from the net plot on all the observation dates commencing from 30 days after sowing. The plant was dried in sun and subsequently in hot air oven at 60°C till constant weight was obtained.

B) Development studies :

1. Days to 50 per cent flowering :

These observations were started from the emergence of flowers in the plot and continued upto the period when fifty per cent of the plants showed flowering.

C) Yield contributing characters :

1. Number of capsules per plant :

The number of capsules of five observation plants were counted and its number per plant was worked out.

2. Number of grains per plant :

The capsules of 5 observation plants were threshed separately and the number of grains were counted. The number of grains per plant were then worked out.

3. Weight of grain per plant :

The weight of grains from five observation plants was recorded and its weight per plant was worked out.

4. 1000 grain weight :

A random sample of 1000 grain from net plot produce of each treatment was selected and 1000 grains were counted and its weight was recorded.

D) Post harvest studies :

1. Grain yield :

The weight of grain per plot was recorded after threshing and cleaning the produce of each net plot. The grain yield per hectare was then worked out.

2. Bhusa yield :

The total weight of plants was taken before threshing and weight of bhusa was obtained by substracting the weight of grain from it.

3. Harvest index :

Harvest index was calculated by using the following formula.

$$H.I. = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

4. Response equation :

The response equation was fitted to the yield data and R^2 value was worked out to observe good fit or otherwise.

E) Chemical studies :

The observational plants at harvest were utilised for chemical analysis. Plant samples were oven dried and put to wiley mill to pass through 20 mesh and used for chemical analysis. Grain samples drawn at randomly from net plot dried and powdered in an electric grinder and used for analysis.

1. Nitrogen content in grain and bhusa :

The nitrogen content in grain and bhusa were estimated by modified Kjeldhal's method (A.O.A.C. 1965).

2. Total nitrogen uptake by the crop (kg/ha) :

Nitrogen uptake by grain and bhusa was calculated by multiplying nitrogen concentration in grain and bhusa with their respective yields per hectare. The total uptake of nitrogen by the crop (kg/ha) was calculated by the addition of uptake of nitrogen by grain and bhusa.

3. Phosphorus content in grain and bhusa :

Phosphorus content in grain and bhusa was determined by modified Olsen's method (Olsen; 1954).

4. Phosphorus uptake by grain and bhusa :

It was determined by multiplying phosphorus content in grain and bhusa with their respective yields. The total uptake of phosphorus by the crop was calculated by the addition of uptake of phosphorus by grain and bhusa.

5. Quality studies :

Oil and protein content are the two important quality attributes in safflower. Protein percentage was determined by multiplying percentage of nitrogen in the grain by the factor 6.25 (A.O.A.C., 1965). Oil percentage in grain was estimated by Soxhlet's ether extraction method (Piper,1966).

3.2.5 Statistical analysis and interpretation of data :

The data recorded was statistically analysed by technique of Analysis of Variance (Fisher and Yates 1963) and test of significance was carried out as given by Cochran and Cox (1967) and Panase and Sukhatme (1967). In the tabular data in text C.D. values have been given for comparison only in cases where the 'F' test was significant; where, it was not significant, figures for S.E. of means only are given.

4. RESULTS

4. RESULTS

4.1 Initial and Final plant stand :

Data pertaining to the initial and final plant stand as influenced by different treatments are presented in Table 7.

The mean initial and final plant stand was 327.37 and 319.89 plants/net plot, respectively.

Fertilizer levels :

The mean initial and final plant stand was not influenced significantly due to different levels of fertilizer application.

Plant densities :

There was significant difference inthe number of plants per net plot at initial stage as well as at harvest due to application of treatment of plant densities.

Interaction :

The number of plants were not affected due to interaction between fertilizer levels and plant densities.

4.2 Growth studies :

Biometric observations were recorded on the various growth characters viz., plant height, spread, number of

Table 7 : Mean number of initial and final plant population count

Treatments	Initial plant population		Final plant population at harvest	
	Net plot	Per ha	Net plot	per ha
Fertilizers (kg/ha)				
N + P_2O_5				
25 + 12.5	327.33	134702	320.33	131822
50 + 25	327.25	134670	319.58	131514
75 + 37.5	327.66	134839	320.00	131686
100 + 50	327.25	134670	319.66	131546
S.E.±	0.74	305	0.42	173
C.D. at 5%	-	-	-	-
Plant Densities (lakh/ha)				
2.25	537.66	221258	530.83	218447
1.50	327.33	134702	349.58	143859
1.00	237.50	97736	230.25	14752
0.75	177.53	73057	168.91	67041
S.E.±	0.74	305	0.42	173
C.D. at 5%	2.13	877	1.22	502
Interaction				
S.E.±	1.85	761	0.85	350
C.D. at 5%	-	-	-	-
General Mean	327.37	134719	319.89	131641

branches and dry matter accumulation per plant at regular interval of 15 days from 30 days onwards.

4.2.1 Plant Height :

Data regarding mean plant height as affected periodically by different treatments are presented in Table 8 and graphically depicted in Fig.2.

The mean plant height at 30 days after sowing was 17.62 cm. It increased progressively as the age of the crop advanced and attained maximum (109.18 cm) at harvest. The plant height was increased rapidly during 45 to 60 days, thereafter it was increased gradually.

Fertilizer levels :

The plant height was influenced significantly throughout the crop growth period due to different levels of fertilizer application except at 60 days after sowing. The application of 100 kg N + 50 kg P_2O_5/ha increased plant height significantly over 25 kg N + 12.5 kg P_2O_5/ha and 50 kg N + 25 kg P_2O_5/ha at all the crop growth stages except at harvest where, it was on par with 50kg N + 25 kg P_2O_5/ha. Further, it was observed that application of 75 kg N + 37.5 kg P_2O_5/ha also increased the plant height significantly over 25 kg N + 12.5 kg P_2O_5/ha during early crop growth stages viz.,30 and 45 days after sowing.

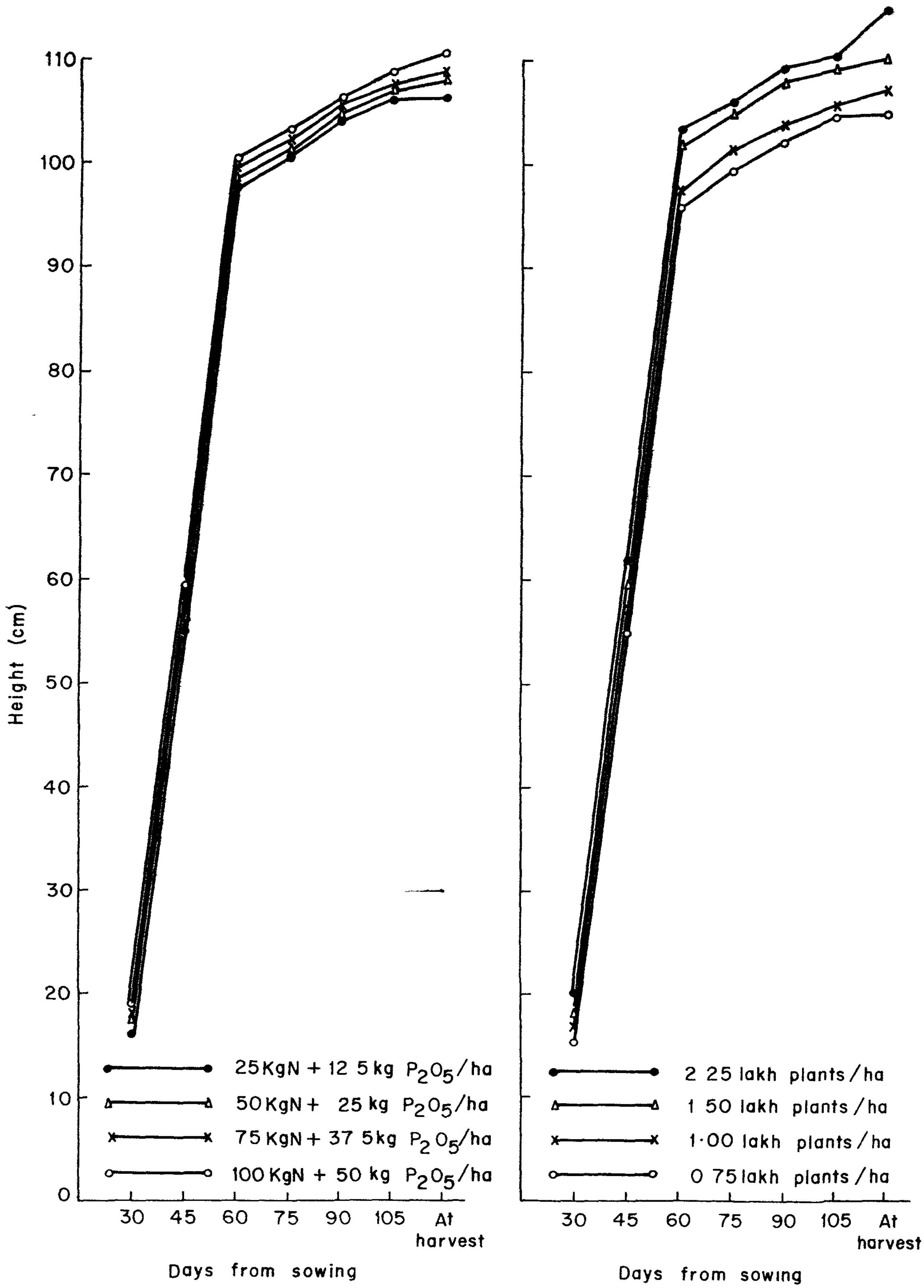


Fig. 2 : Mean plant height (cm) as affected periodically by various treatments.

Table 8 : Mean plant height (cm) as affected periodically by various treatments

Treatments	Days after sowing						At harvest
	30	45	60	75	90	105	
Fertilizers (kg/ha) $N + P_2O_5$							
25 + 12.5	16.61	55.75	98.21	100.92	103.95	106.73	106.96
50 + 25	17.38	56.53	98.55	101.03	104.23	106.91	108.45
75 + 37.5	18.13	57.83	99.03	101.83	105.18	107.66	108.65
100 + 50	18.35	59.51	100.28	103.75	106.51	109.28	110.68
S.E. ±	0.39	0.62	0.79	0.75	0.72	0.80	0.78
C.D. at 5%	1.12	1.78	-	2.16	2.07	2.30	2.24
Plant densities (lakh/ha)							
2.25	19.75	60.08	102.55	104.91	108.31	110.35	115.53
1.50	18.13	58.58	101.33	104.03	106.95	109.55	110.13
1.00	17.06	56.68	96.83	100.08	102.96	105.81	107.85
0.75	15.53	54.26	95.36	98.48	101.73	104.85	105.21
S.E. ±	0.39	0.62	0.79	0.75	0.72	0.80	0.78
C.D. at 5%	1.12	1.78	2.27	2.16	2.07	2.30	2.24
Interaction							
S.E. ±	0.79	1.73	1.83	1.50	1.42	1.61	1.55
C.D. at 5%	-	-	-	-	-	-	-
General Mean	17.62	57.40	99.01	101.87	104.97	107.64	109.18

Plant Densities :

The differences in plant height due to different levels of plant densities were found to be significant at all the crop growth stages. The plant density of 2.25 lakh plants/ha increased plant height significantly whereas plant density of 0.75 lakh plants/ha decreased plant height significantly as compared to other plant densities on 30 days after sowing. The higher plant densities of 2.25 and 1.50 lakh plants/ha recorded significantly more plant height than plant densities of 1.00 and 0.75 lakh plants/ha from 45 to 105 days after sowing. The height of safflower was increased significantly with increased levels of plant densities at harvest.

Interaction :

Plant height was not influenced due to interaction effects at all stages.

4.2.2 Plant Spread :

Data pertaining to the mean plant spread as affected periodically by various treatments are presented in Table 9 and graphically depicted in Fig.3.

The mean plant spread was increased gradually with the advanced age of crop. The maximum spread of 62.84 cm was recorded at harvest. The rapid increase in plant apread was observed between 45 to 60 days after sowing.

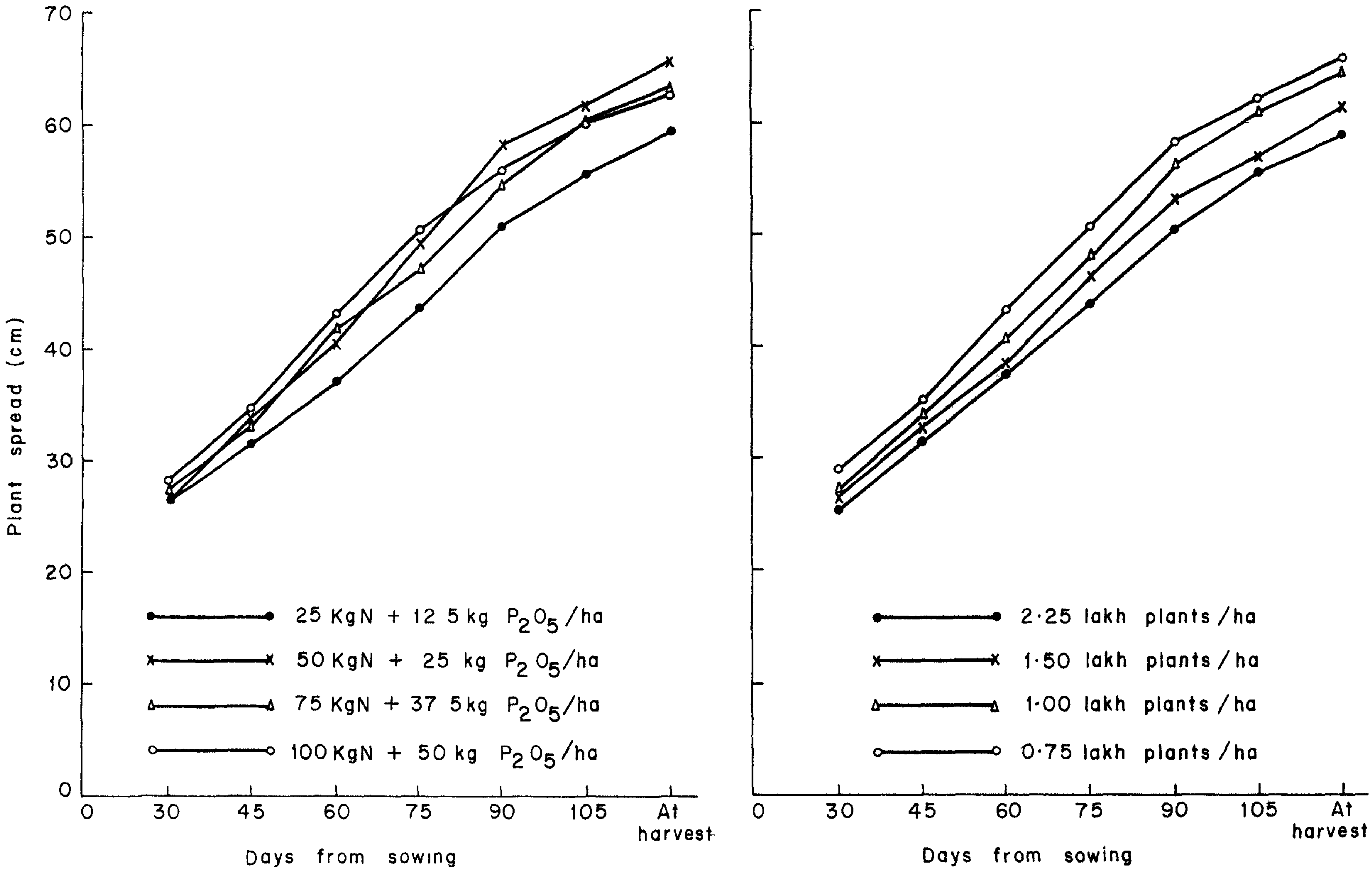


Fig. 3 : Mean plant spread (cm) as affected periodically by various treatments.

Table 9 : Mean plant spread (cm) as affected by various treatments periodically

Treatments	Days after sowing						At harvest
	30	45	60	75	90	105	
Fertilizer (kg/ha) N + P_2O_5							
25 + 12.5	26.23	31.28	37.08	43.71	50.95	55.38	59.41
50 + 25	26.20	33.85	40.21	49.31	57.88	61.46	65.46
75 + 37.5	27.65	33.65	41.45	46.86	54.91	60.03	63.46
100 + 50	28.30	34.68	43.11	50.43	55.88	60.16	63.05
S.E. ±	0.60	0.64	0.99	1.26	1.35	1.27	1.04
C.D.at 5%	1.72	1.84	2.84	3.62	3.88	3.65	2.99
Plant densities (lakh/ha)							
2.25	25.30	31.46	37.51	44.10	50.68	55.73	59.00
1.50	26.90	32.85	38.66	46.51	53.46	57.30	61.46
1.00	27.23	33.91	40.83	48.65	56.61	61.26	64.68
0.75	28.95	35.23	43.61	51.06	58.86	62.75	66.25
S.E. ±	0.60	0.64	0.99	1.26	1.35	1.27	1.04
C.d.at 5%	1.72	1.84	2.84	3.62	3.88	3.65	2.99
Interaction							
S.E. ±	1.21	1.29	1.99	2.53	2.71	2.55	2.09
C.D. at 5%	-	-	-	-	-	-	-
General mean	27.10	33.36	40.29	47.57	54.90	59.25	62.84

Fertilizer Levels :

The plant spread was significantly decreased with lower level of fertilizer (25 kg N + 12.5 kg P_2O_5/ha) than higher levels of fertilizers which were on par with each other at all the crop growth stages except on 30 and 75 days after sowing where, it was on par with 50kg N + 25 kg N P_2O_5/ha and 75 kg N + 37.5 kg P_2O_5/ha. The application of 100 kg N + 50 kg P_2O_5/ha increased the plant spread significantly over 50 kg N + 25 kg P_2O_5/ha on 30 days after sowing.

Plant Densities :

The plant density of 0.75 lakh plants/ha increased plant spread significantly over plant densities of 1.50 and 2.25 lakh plants/ha. Plant density of 1.00 lakh plants/ha also increased plant spread as compared to 2.25 lakh plants/ha from 30 to 90 days after sowing. The higher plant densities of 2.25 and 1.50 lakh plants/ha decreased plant spread significantly than plant densities of 1.00 and 0.75 lakh plants/ha on 105 days after sowing and at harvest.

Interaction :

Interaction effects between fertilizer levels and plant densities were found to be absent at all stages of growth.

4.2.3 Main Branches :

Data regarding mean number of main branches/plant as influenced periodically by various treatments are presented in Table 10.

The mean number of main branches after 45 days was 14.22 and it gradually increased with an increase in the age of crop and reached to its maximum (20.64) at harvest.

Fertilizer Levels :

The mean number of main branches/plant differed significantly at all the crop growth stages. The application of 100 kg N + 50 kg P_2O_5/ha increased number of main branches per plant over other fertilizer levels at all growth stages except on 45 days after sowing and at harvest where it was on par with 75 kg N + 37.5 kg P_2O_5/ha. The - number of main branches/plant were significantly reduced due to application of 25 kg N + 12.5 kg P_2O_5/ha than other fertilizer levels on 45, 60 and 75 days after sowing. The number of main branches/plant were increased significantly due to application of 75 kg N + 37.5 kg P_2O_5/ha as compared to 25 kg N + 12.5 kg P_2O_5/ha on 90 days after sowing.

Plant Densities :

The mean number of main branches/plant were affected significantly by various plant densities upto 75 days after sowing. The lower plant densities of 0.75 and 1.00 lakh plants/ha increased the number of main branches/plant significantly over higher plant densities of 1.50 and 2.25 lakh

Table 10 : Mean number of main branches per plant as affected by various treatments periodically

Treatments	Days after sowing					At harvest
	45	60	75	90	105	
Fertilizers (kg/ha) $N + P_2O_5$						
25 + 12.5	12.03	13.25	14.28	15.85	17.03	18.28
50 + 25	13.83	15.58	16.76	17.55	18.63	19.56
75 + 37.5	14.95	16.28	17.53	18.91	19.91	20.88
100 + 50	16.08	18.55	21.14	22.31	23.36	23.90
S.E. ±	0.47	0.48	0.85	1.02	1.05	1.18
C.D. at 5%	1.35	1.38	2.44	2.93	3.02	3.39
Plant densities (lakh/ha)						
2.25	12.31	13.52	15.29	16.76	17.75	19.00
1.50	13.30	15.23	16.48	17.96	19.00	19.51
1.00	15,11	16.55	17.91	19.70	20.50	21.21
0.75	16.18	18.41	20.03	20.21	21.60	22.83
S.E. ±	0.47	0.48	0.85	1.02	1.05	1.18
C.D. at 5%	1.35	1.38	2.44	-	-	-
Interaction						
S.E. ±	0.94	0.96	1.71	2.05	2.10	2.37
C.D. at 5%	-	-	-	-	-	-
General Mean	14.22	15.91	17.42	18.65	19.72	20.64

plants/ha on 45 and 75 days after sowing, but plant densities of 1.00 and 1.5 lakh plants/ha were on par on 75 days after sowing. The number of main branches/plant were significantly increased with 0.75 lakh plants/ha and significantly decreased with the plant density of 2.25 lakh plants/ha on 60 days after sowing.

Interaction :

The interaction effects were not present during all the stages of growth.

..4.2.4 Sub-branches :

Data on mean number of sub-branches as affected by various treatments are presented in Table 11.

The mean number of sub-branches/plant were increased gradually as the crop age advanced. The minimum (18.59) and maximum (20.75) number of sub-branches/plant were observed on 60 days after sowing and at harvest, respectively.

Fertilizer Levels :

The mean number of sub-branches/plant were differed significantly due to different levels of fertilizers at all the crop growth stages. The application of 100 kg N + 250 kg P_2O_5/ha increased number of sub-branches/plant as compared to other fertilizer levels at all the crop growth stages. Further, it was observed that application of 75 kg

Table 11 : Mean number of sub-branches per plant as influenced periodically by various treatments

Treatments	Days after sowing				At harvest
	60	75	90	105	
Fertilizers (kg/ha) $N + P_2O_5$					
25 + 12.5	15.83	17.70	19.86	21.13	21.88
50 + 25	18.28	19.65	21.63	23.35	24.71
75 + 37.5	18.53	19.96	22.16	26.26	27.65
100 + 50	21.75	23.38	28.18	31.45	33.11
S.E. ±	0.89	1.07	1.41	1.56	1.77
C.D. at 5%	2.55	3.07	4.05	4.48	5.09
Plant densities (lakh/ha)					
2.25	16.36	18.33	21.28	23.15	24.81
1.50	17.35	19.83	22.50	23.50	25.68
1.00	20.31	21.21	23.76	27.56	28.07
0.75	20.36	21.26	24.23	27.88	28.16
S.E. ±	0.89	1.07	1.41	1.56	1.77
C.D. at 5%	2.55	-	-	-	-
Interaction					
S.E. ±	1.78	2.15	2.82	3.13	3.55
C.D. at 5%	-	-	-	-	-
General Mean	18.59	20.17	22.94	25.52	26.75

N + 37.5 kg P_2O_5/ha also increased number of sub-branches/ plant over 25 kg N + 12.5 kg P_2O_5/ha on 60 and 105 days after sowing and at harvest.

Plant Densities :

The mean number of sub-branches/plant were affected significantly due to different plant densities only on 60 days after sowing. The lower plant densities of 0.75 and 1.00 lakh plants/ha were found to be on par with each other, but increased the number of sub-branches/plant significantly over higher plant densities of 1.50 and 2.25 lakh plants/ha which were also on par with each other at 60 days after sowing.

Interaction :

The interaction between fertilizer levels and plant densities did not differ significantly during all the stages of growth.

4.2.5 Dry matter :

Data pertaining to mean dry matter accumulation per plant as influenced by various treatments are presented in Table 12 and graphically depicted in Fig.4.

The mean dry matter accumulation per plant was 3.57 g on 30 days after sowing. The dry matter accumulation was progressively increased with the increase in age of the

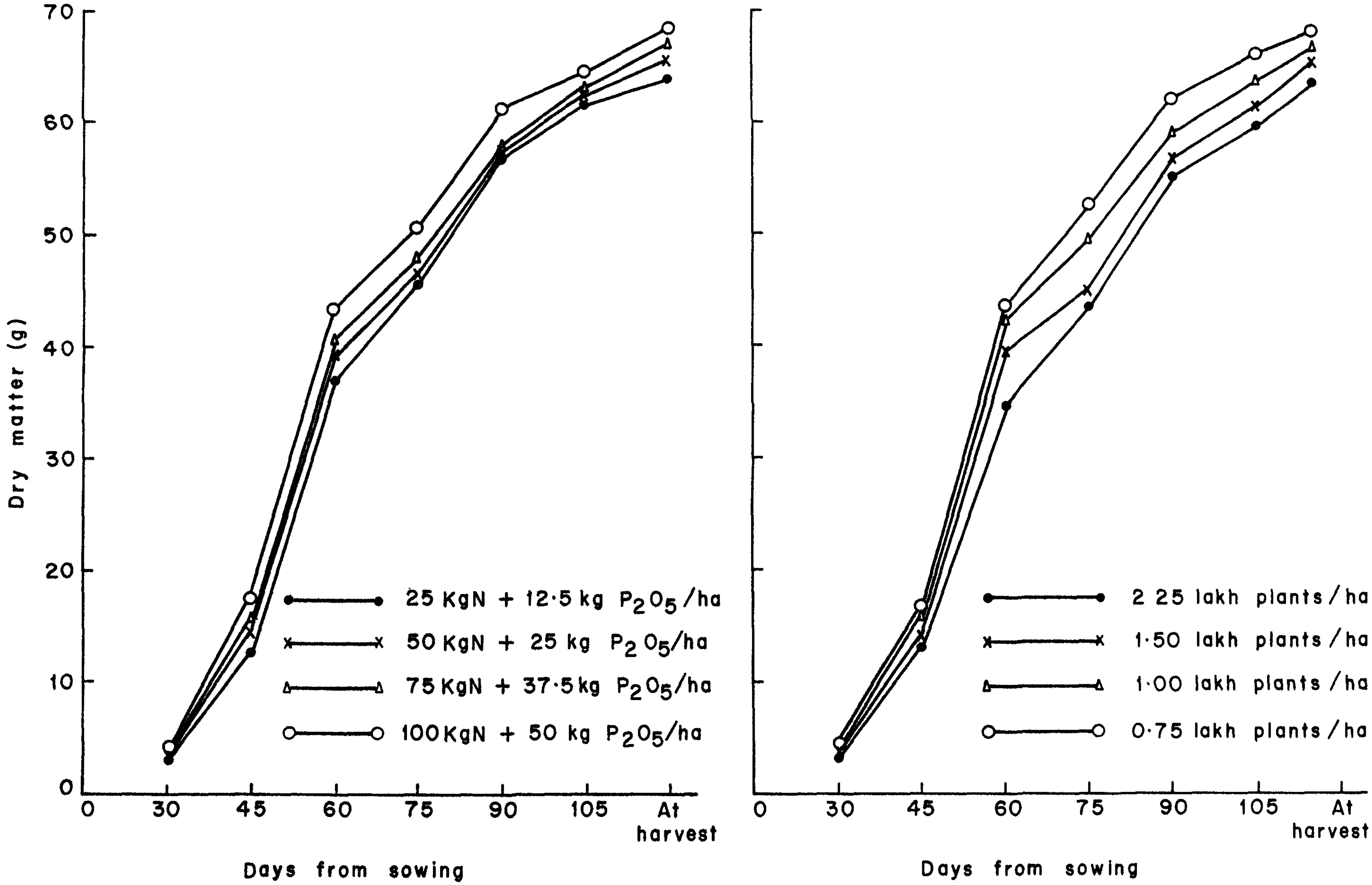


Fig. 4 : Mean dry matter production (g) per plant as affected periodically by various treatments.

Table 12 : Mean dry matter production (g) per plant as affected periodically by various treatments

Treatments	Days after sowing						At harvest
	30	45	60	75	90	105	
Fertilizers(kg/ha) $N + P_2O_5$							
25 + 12.5	3.38	12.65	36.83	45.70	56.51	61.52	63.75
50 + 25	3.43	14.43	38.898	46.62	57.09	62.09	65.34
75 + 37.5	3.65	15.55	40.66	47.39	57.38	62.29	66.94
100 + 50	3.84	17.44	43.47	50.70	61.18	64.44	68.61
S.E. ±	0.179	0.623	1.08	0.99	0.93	0.90	0.67
C.D. at 5%	-	1.79	3.10	2.84	2.67	-	1.92
Plant densities (lakh/ha)							
2.25	3.06	13.27	34.51	43.82	54.58	59.54	63.74
1.50	3.36	14.27	39.50	44.82	56.53	61.50	65.68
1.00	3.47	15.97	42.34	49.42	58.92	63.29	66.52
0.75	4.40	16.55	43.51	52.36	62.13	66.04	68.07
S.E. ±	0.179	0.623	1.08	0.99	0.93	0.90	0.67
C.D. at 5%	0.51	1.79	3.10	2.84	2.67	2.58	1.92
Interaction							
S.E. ±	0.358	1.246	2.50	1.98	1.87	1.87	1.35
C.D. at 5%	-	-	-	-	-	-	-
General Mean	3.57	15.00	39.96	47.60	58104	62.58	66.08

crop. The rate of dry matter accumulation per plant was rapid during the period from 45 to 90 days after sowing. The maximum dry matter accumulation of 66.08 g per plant was observed at harvest.

Fertilizer Levels :

Dry matter accumulation per plant was significantly increased due to application of 100 kg N + 50 kg P_2O_5/ha as compared to 25 kg N + 12.5 kg P_2O_5/ha and 50 kg N + 25 kg P_2O_5/ha on 45, 60, 75 and 90 days after sowing and at harvest. Further, it was observed that application of 75 kg N + 37.5 kg P_2O_5/ha also increased dry matter accumulation per plant significantly over 25 kg N + 12.5 kg P_2O_5/ha on 45 and 60 days after sowing and at harvest.

Plant Densities :

The lower plant density of 0.75 lakh plants/ha accumulated more dry matter as compared to higher plant densities of 1.50 and 2.25 lakh plants/ha at all the crop growth stages. Further, it was noticed that the plant density of 1.00 lakh plants/ha also accumulated more dry matter over the plant density of 2.25 lakh plants/ha at all the crop growth stages, except on 30 days after sowing. The higher plant density of 2.25 lakh plants/ha significantly decreased dry matter per plant than other plant densities on 60 days after sowing and at harvest.

Interaction :

Dry matter accumulation was not significantly influenced due to interaction between fertilizer levels and plant densities.

4.3 Days to 50 per cent flowering :

Data regarding days to 50 per cent flowering as affected by various treatments are presanted in Table 13.

It was noticed from the data in Table 13 that the mean days required for 50 per cent flowering were 85.94.

Fertilizer Levels :

The application of 100 kg N + 50 kg P_2O_5/ha required significantly more number of days for 50 per cent flowering as compared to 25 kg N + 12.5 kg P_2O_5/ha and 50 kg N + 25 kg P_2O_5/ha. The application of 25 kg N + 12.5 kg P_2O_5/ha required significantly less number of days for 50 per cent flowering.

Plant Densities :

The number of days to 50 per cent flowering were not influenced significantly due to different plant densities.

Interaction:

Interaction effects were not present.

Table 13 : Days to 50 per cent flowering and mean number of capusles per plant as affected periodically by various treatments

Treatments	Days to 50 per cent flowering	Number of capsules/plant		
		Days of sowing		At harvest
		90	105	
Fertilizers (kg/ha) $N + P_2O_5$				
25 + 12.5	83.55	24.85	27.16	32.14
50 + 25	85.98	29.20	31.50	34.36
75 + 37.5	86.73	31.69	33.81	35.99
100 + 50	87.33	33.90	36.00	36.92
S.E. ±	0.29	2.95	2.91	0.46
C.D. at 5%	0.85	-	-	1.30
Plant densities (lakh/ha)				
2.25	85.59	25.12	28.09	32.39
1.50	85.88	28.62	30.84	35.29
1.00	86.07	30.06	32.30	35.73
0.75	86.40	34.85	35.17	36.50
S.E. ±	0.13	2.95	2.91	0.46
C.D. at 5%	-	8.48	-	1.30
Interaction				
S.E. ±	0.61	5.90	5.82	0.92
C.D. at 5%	-	-	-	-
General Mean	85.94	29.91	32.10	34.85

4.4 Yield contributing characters :

4.4.1. Number of capsules per plant :

Data pertaining to mean number of capsules per plant as influenced by various treatments are presented in Table 13.

It would be seen from the data presented in Table 13 that the mean number of capsules per plant were gradually increased as the crop age was advanced. The maximum (34.85) mean number of capsules per plant were observed at harvest.

Fertilizer Levels :

The number of capsules per plant differed significantly due to different levels of fertilizers only at harvest The application of 100 kg N + 50 kg P_2O_5/ha and 75 kg N + 37.5 kg P_2O_5/ha increased number of capsules per plant significantly over 25 kg N + 12.5 kg P_2O_5/ha and 30 kg N + 25 kg P_2O_5/ha at harvest. Further, it was observed that the application of 50 kg N + 25 kg P_2O_5/ha also increased number of capsules per plant significantly over 25 kg N + 12.5 kg P_2O_5/ha.

Plant Densities :

The number of capsules per plant were significantly decreased with the higher plant density of 2.25 lakh plants/ha as compared to lower plant densities which were found to be on par with each other on 90 days after sowing and at harvest.

Interaction :

The number of capsules per plant were not affected significantly due to interaction between fertilizer levels and plant densities.

4.4.2 Number of grains per plant :

Data regarding number of grains per plant as affected by different treatments are presented in Table 14 and graphically depicted in Fig.5.

Data presented in Table 14 revealed that the mean number of grains per plant were 354.98.

Fertilizer Levels :

The number of grains per plant were not differed significantly due to different levels of fertilizers. However, the beneficial increase in number of grains per plant was observed with increased levels of fertilizer application.

Plant Densities :

The number of grains per plant were significantly affected due to different plant densities. The number of grains per plant were increased significantly with decreased levels of plant densities.

Interaction :

Interaction effects due to fertilizer levels and plant densities were found to be absent.

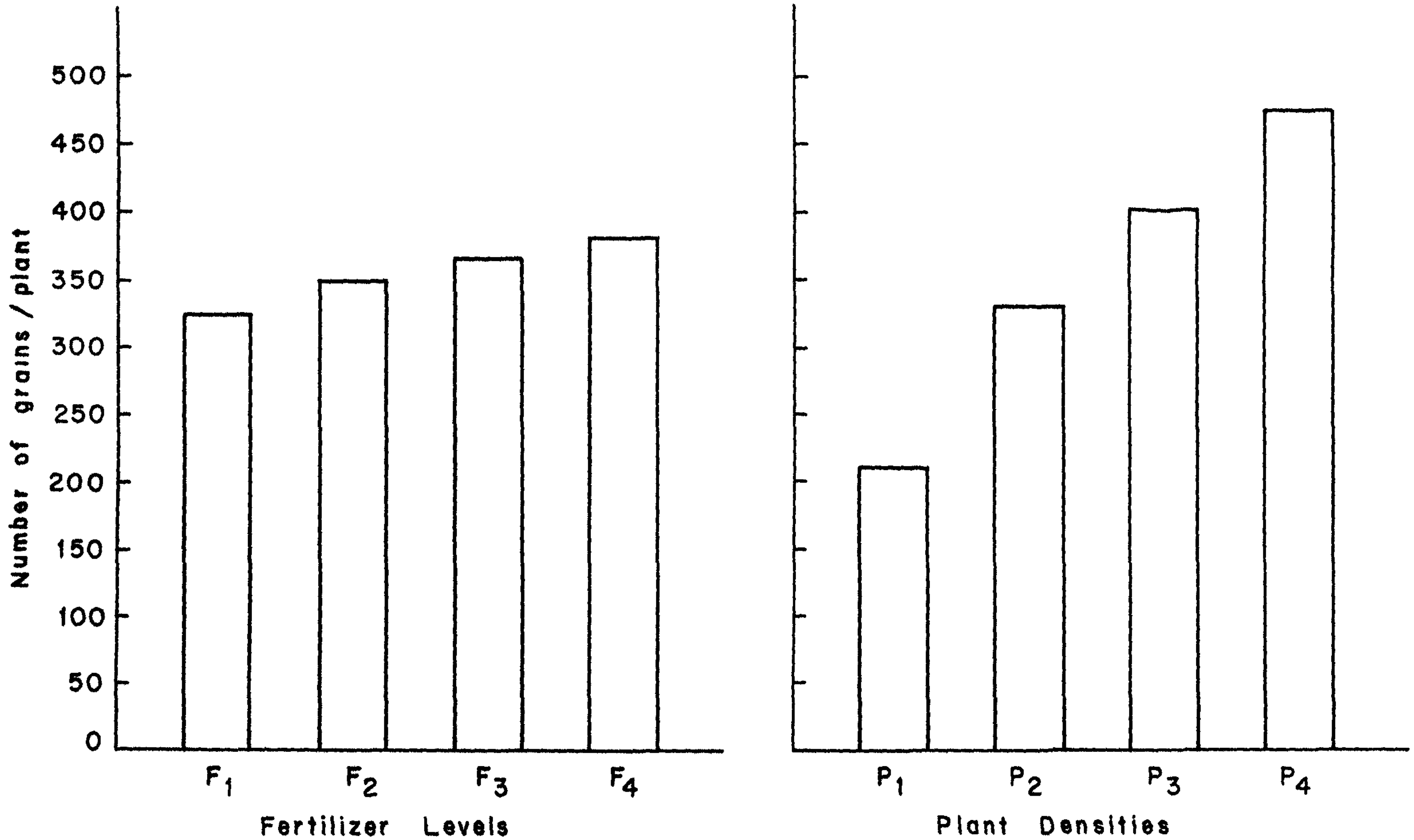


Fig. 5 : Mean number of grains per plant at harvest.

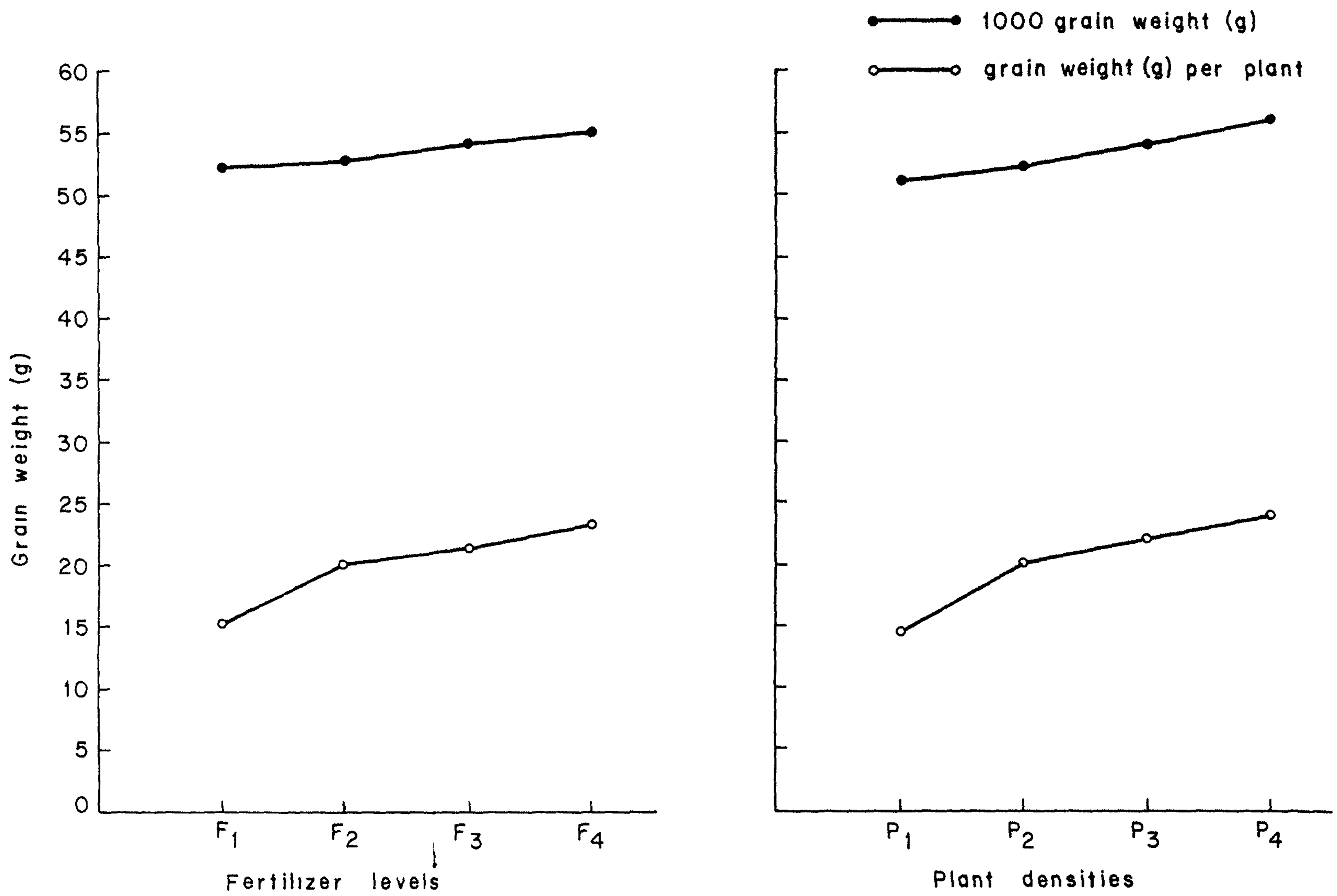


Fig. 6 : Mean thousand grain weight (g) and grain weight (g) per plant as affected by various treatments.

Table 14 : Mean number of grains and its weight/plant and 1000 grain weight as affected by various treatments

Treatments	Number of grains /plant	Grain weight (g)/plant	1000 grain weight (g)
Fertilizers (kg/ha) $N + P_2O_5$			
25 + 12.5	325.78	15.83	52.57
50 + 25	348.69	20.78	52.85
75 + 37.5	365.65	21.25	53.95
100 + 50	380.27	23.25	54.97
S.E. ±	20.07	1.36	0.45
C.D. at 5%	-	3.91	1.29
Plant densities (lakh/ha)			
2.25	210.22	14.81	51.01
1.50	331.61	20.01	52.66
1.00	403.05	22.13	54.37
0.75	474.53	23.90	56.29
S.E. ±	20.07	1.36	0.45
C.D. at 5%	57.72	3.91	1.29
Interaction			
S.E. ±	40.14	2.73	0.90
C.D. at 5%	-	-	-
General mean	354.98	20.23	53.58

4.4.3 Weight of grains per plant :

Data pertaining to the mean grain weight per plant as influenced by various treatments are presented in Table 14 and graphically depicted in Fig.6.

It was noticed from the data presented in Table 14 that the mean grain weight per plant was 20.23 g.

Fertilizer Levels :

The application of 25 kg N + 12.5 kg P_2O_5/ha decreased grain weight per plant significantly as compared to higher fertilizer levels which were on par with each other.

Plant Densities :

The grain weight was significantly reduced with highest plant density of 2.25 lakh plants/ha as compared to lower plant densities which were on par with each other.

Interaction :

The interaction effects were not differed significantly due to fertilizer levels and plant densities.

4.4.4 1000 grain weight :

Data regarding 1000 grain weight as affected by different treatments are presented in Table 14 and graphically depicted in Fig.6.

It was observed from the data in Table 14 that the mean 1000 grain weight was 53.58 g.

Fertilizer levels :

The application of 100 kg N + 50 kg P_2O_5/ha increased 1000 grain weight significantly over 25 kg N + 12.5 kg P_2O_5/ha and 50 kg N + 25 kg P_2O_5/ha. Further, it was obserfved that application of 75 kg N + 37.5 kg P_2O_5/ha also increased 1000 grain weight significantly as compared to 25 kg N + 12.5 kg P_2O_5/ha.

Plant Densities :

The 1000 grain weight was significantly increased with decreased levels of plant densities.

Interaction :

The interaction between fertilizer levels and plant densities was not present.

4.5 Yields :

Data pertaining to mean grain and bhusa yields and harvest index as influenced by different treatments are presented in Table 15 and grain and bhusa yields are represented graphically in Fig.7.

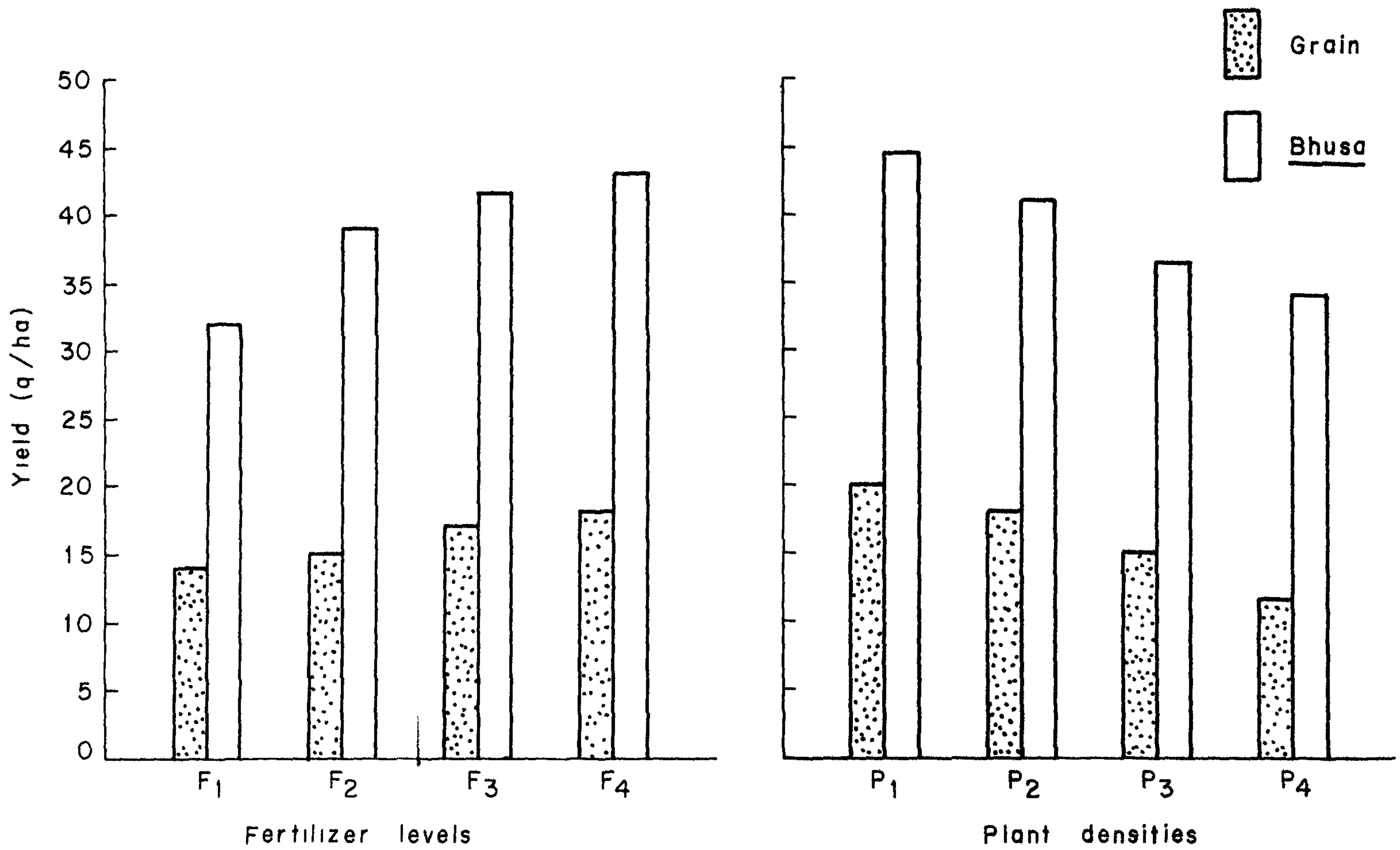


Fig. 7 : Mean grain and <u>bhusa</u> yield (q/ha) as influenced by various treatments.

Table 15 : Mean yield and harvest index as affected by various treatments

Treatments	Yield (q)/ha)		Harvest index
	Grain	Bhusa	
Fertilizers (kg/ha) $N + P_2O_5$			
25 + 12.5	14.27	32.34	30.62
50 + 25	15.31	38.88	28.25
75 + 37.5	17.24	41.68	29.26
100 + 50	17.53	43.00	28.96
S.E. ±	0.40	0.46	-
C.D. at 5%	1.15	1.32	-
Plant Densities (lakh/ha)			
2.25	20.37	44.40	31.45
1.50	17.90	41.11	30.33
1.00	14.85	36.41	28.97
0.75	11.39	33.99	25.10
S.E. ±	0.40	0.46	-
C.D. at 5%	1.15	1.32	-
Interaction			
S.E. ±	0.91	0.92	-
C.D. at 5%	-	-	-
General mean	16.10	38.98	29.12

4.5.1 Grain yield :

Data presented in Table 15 showed that the mean grain yield was 16.10 q/ha.

Fertilizer Levels :

The application of 100 kg N + 50 kg P_2O_5/ha and 75 kg kg N + 37.5 kg P_2O_5/ha were on par but increased grain yield significantly over 50 kg N + 25 kg P_2O_5/ha and 25 kg N + 12.5 kg P_2O_5/ha which were also on par with each other. The grain yield was increased by 7.29, 20.81 and 22.85 per cent due to application of 50 kg N + 25 kg P_2O_5/ha, 75 kg N + 37.5 kg P_2O_5/ha and 100 kg N + 50 kg P_2O_5/ha, respectively, over 25 kg N + 12.5 kg P_2O_5/ha.

Plant Densities :

The grain yield was significantly increased with increased levels of plant densities. The plant densities of 2.25,1.50 and 1.00 lakh plants/ha increased grain yield by 78.84, 57.46 and 30.38 per cent, respectively, over the plant density of 0.75 lakh plants/ha.

Interaction :

Interaction between fertilizer levels and plant densities was not present.

4.5.2 Bhusa yield :

It would be seen from the data in Table 15 that the mean bhusa yield was 38.98 q/ha.

Fertilizer Levels :

The application of 100 kg N + 50 kg P_2O_5/ha and 75 kg N + 37.5 kg P_2O_5/ha were on par; however, increased bhusa yield significantly over 50 kg N + 25 kg P_2O_5/ha and 25 kg N + 12.5 kg P_2O_5/ha. Further, it was observed that the application of 50 kg N + 25 kg P_2O_5/ha also gave significantly more bhusa yield than 25 kg N + 12.5 kg P_2O_5/ha. The application of 50 kg N + 25 kg P_2O_5/ha, 75 kg N + 37.5 kg P_2O_5/ha and 100 kg N + 50 kg P_2O_5/ha increased bhusa yield by 22.22, 28.98 and 32.96 per cent, respectively, over 25 kg N + 12.5 kg P_2O_5/ha.

Plant Densities :

The bhusa yield was significantly increased with increased levels of plant densities. The plant densities of 1.00, 1.50 and 2.25 lakh plants/ha increased bhusa yield by 7.12,20.95 and 30.63 per cent, respectively, over the plant density of 0.75 lakh plants/ha.

Interaction :

The interaction effects due to fertilizer levels and plant densities were absent.

4.5.3 Harvest index :

It was noticed from the data in Table 15 that the mean harvest index was 29.12.

Fertilizer Levels :

The maximum harvest index of 30.62 was recorded due to application of 25 kg N + 12.5 kg P_2O_5/ha followed by application of 75 kg N + 37.5 kg P_2O_5/ha.

Plant Densities :

The harvest index was decreased gradually with decreased plant densities. The maximum (31.45) and minimum (25.10) harvest index was observed in plant densities of 2.25 and 0.75 lakh plants/ha respectively.

4.6 Chemical studies :

The inferences of chemical studies are based on mean values.

Data regarding nitrogen and phosphorus content in grain and bhusa as affected by various treatments are presented in Table 16.

4.6.1 Nitrogen content in grain :

Data presented in Table 16 revealed that the mean nitrogen content in grain was 2.566 per cent.

Fertilizer Levels :

The nitrogen content in grain was increased gradually with increased levels of fertilizer application. The maximum nitrogen content of 2.713 per cent was observed due to application of 100 kg N + 50 kg P_2O_5/ha.

Table 16 : Mean nitrogen and phosphorus content ingrain and bhusa as influenced by various treatments

Treatments	Nitrogen content (per cent)		Phosphorus content (Per cent	
	Grain	Bhusa	Grain	Bhusa
Fertilizers (kg/ha)				
N + P_2O_5				
25 + 12.5	2.411	0.438	0.439	0.175
50 + 25	2.524	0.586	0.486	0.194
75 + 37.5	2.637	0.659	0.593	0.209
100 + 50	2.713	0.763	0.637	0.219
Plant Densities (lakh/ha)				
2.25	2.602	0.643	0.535	0.201
1.50	2.573	0.589	0.520	0.187
1.00	2.535	0,557	0.506	0.169
0.75	2.533	0.521	0 483	0.159
General mean	2.566	0.594	0.524	0.189

Plant Densities:

The nitrogen content of grain decreased gradually with decreased levels of plant densities. The lowest nitrogen content of 2.533 per cent was observed in plant density of 0.75 lakh plants/ha.

4.6.2 Nitrogen content in bhusa :

It was noticed from the data presented in Table 16 that the mean nitrogen content in bhusa was 0.594 per cent.

Fertilizer Levels :

The nitrogen content in bhusa was increased progressively with increased levels of fertilizer application and reached to its maximum of 0.763 per cent due to application 100 kg N + 50 kg P_2O_5/ha.

Plant Densities :

The nitrogen content of bhusa was increased gradually with increased levels of plant densities. The maximum (0.643 per cent) nitrogen content of bhusa was observed in plant density of 2.25 lakh plants/ha.

4.6.3 Phosphorus content in grain :

It was observed from the data in Table 16 that the mean phosphorus content of grain was 0.524 per cent.

Fertilizer Levels :

The phosphorus content in grain was progressively increased with increased levels of fertilizer application. The maximum phosphorus content of 0.637 per cent was recorded with the application of 100 kg N + 50 kg P_2O_5/ha.

Plant Densities :

The phosphorus content in grain was decreased gradually with decreased levels of plant densities. The minimum phosphorus content (0.521 per cent) was observed in plant density of 0.75 lakh plants/ha.

4.6.4 Phosphorus content in bhusa :

Data presented in Table 16 indicated that the mean phosphorus content in bhusa was 0.189 per cent.

Fertilizer Levels :

The beneficial increase in phosphorus content in bhusa was recorded due to increased levels of fertilizer application.

Plant Densities :

The phosphorus content in bhusa was increased gradually with increased levels of plant densities. The highest phosphorus content (0.201 per cent) was noticed in the [illegible] plant density of 2.25 lakh plants/ha.

4.7 Uptake studies :

Data regarding uptake of N and P by grain and bhusa and total N and P uptake by safflower as influenced by various treatments are presented in Table 17.

4.7.1 Nitrogen uptake by grain :

It could be seen from the data in Table 17 that the mean nitrogen uptake by grain was 41.36 kg/ha.

Fertilizer Levels :

Uptake of nitrogen by grain increased progressively with increased levels of fertilizer application. The nitrogen uptake by grain was lowest (29.56 kg/ha) due to application of 25 kg N + 12.5 kg P_2O_5/ha, whereas, it was highest (52.23 kg/ha) due to application of 100 kg N + 50 kg P_2O_5/ha.

Plant Densities :

Uptake of nitrogen by grain was decreased rapidly with decreased plant densities. It was observed that the maximum (49.40 kg/ha) nitrogen uptake was observed in plant density of 2.25 lakh plants/ha; whereas, it was minimum (34.18 kg/ha) with the plant density of 0.75 lakh plants/ha.

4.7.2 Nitrogen uptake by bhusa :

Data presented in Table 17 showed that the mean nitrogen uptake by bhusa was 24.18 kg/ha.

Table 17 : Mean nitrogen and phosphorus uptake by grain by and bhusa as affected by different treatments

Treatments	Nitrogen uptake (kg/ha)			Phosphorus uptake (kg/ha)		
	Grain	Bhusa	Total	Grain	Bhusa	Total
Fertilizers (kg/ha)						
$N + P_2O_5$						
25 + 12.5	29.56	14.05	43.61	5.22	5.84	11.06
50 + 25	38.09	21.15	59.24	7.48	6.99	14.47
75 + 37.5	41.89	27.89	69.78	9.61	8.25	17.86
100 + 50	52.23	33.36	85.59	11.94	8.99	20.93
Plant Densities (lakh/ha)						
2.25	49.40	25.98	75.36	10.33	8.58	18.91
1.50	45.39	24.63	70.02	8.42	7.90	16.32
1.00	40.13	23.87	64.00	7.21	6.96	14.17
0.75	34.14	22.53	56.71	6.77	6.31	12.48
General mean	41.36	24.18	65.54	8.37	7.48	15.85

Fertilizer Levels :

Uptake of nitrogen by bhusa was increased rapidly with increased levels of fertilizer application. The maximum nitrogen uptake of 33.36 kg/ha by bhusa was recorded due to application of 100 kg N + 50 kg P_2O_5/ha.

Plant Densities :

Nitrogen uptake by bhusa was decreased gradually with decreased levels of plant densities. The maximum nitrogen uptake of 25.98 kg/ha by bhusa was observed in plant density of 2.25 lakh plants/ha.

4.7.3 Total nitrogen uptake :

It is seen from the data presented in Table 17 that the mean total nitrogen uptake was 65.54 kg/ha.

Fertilizer Levels :

Total nitrogen uptake was increased rapidly with increased levels of fertilizers. The maximum total nitrogen uptake of 85.59 kg/ha was recorded due to application of 100 kg N + 50 kg P_2O_5/ha.

Plant Densities :

Total nitrogen uptake was increased progressively with increased levels of plant densities. The maximum (75.36 kg/ha) and minimum (56.71 kg/ha) total nitrogen uptake was observed in plant densities of 2.25 and 0.75 lakh plants/ha, respectively.

4.7.4 Phosphorus uptake by grain :

Data presented in Table 17 showed that the mean phosphorus uptake by grain was 8.87 kg/ha.

Fertilizer Levels :

Uptake of phosphorus by grain was increased progressively with increased levels of fertilizer application. The maximum uptake of phosphorus (11.94 kg/ha) was noticed due to application of 100 kg N + 50 kg P_2O_5/ha.

Plant Densities :

Phosphorus uptake by grain was decreased gradually with decreased levels of plant densities. The minimum (6.17 kg/ha) and maximum (10.33 kg/ha) uptake of phosphorus by grain was observed with the plant densities of 0.75 and 2.25 lakh plants/ha, respectively.

4.7.5 Phosphorus uptake by bhusa :

It was observed from the data in Table 17 that the mean phosphorus uptake by bhusa was 7.48 kg/ha.

Fertilizer Levels :

The progressive increase in phosphorus uptake by bhusa was observed with increased levels of fertilizer application. Themaximum (8.99 kg/ha) uptake of phosphorus was noticed due to application of 100 kg N + 50 kg P_2O_5/ha.

Plant Densities :

The phosphorus uptake by <u>bhusa</u> was slowly increased with increased levels of plant densities.

4.7.6 Total phosphorus uptake :

Data presented in Table 17 showed that the mean total phosphorus uptake was 15.85 kg /ha.

Fertilizer Levels :

The application of increased levels of fertilizers increased total phosphorus uptake progressively. The minimum (11.06 kg/ha) and maximum (20.93 kg/ha) total phosphorus uptake was recorded due to application of 25 kg N + 12.5 kg P_2O_5/ha and 100 kg N + 50 kg P_2O_5/ha, respectively.

Plant Densities :

Total phosphorus uptake was increased gradually with increased levels of plant densities. The maximum total phosphorus uptake of 18.91 kg/ha was observed with the plant density of 2.25 lakh plants/ha.

4.8 Quality studies :

The oil and protein content are the important quality attributes in safflower. Data pertaining oil and protein content in grain are presented in Table 18.

4.8.1 Oil content :

It was observed from the data presented in Table 18 that the mean oil content of safflower grain was 29.17 per cent.

Fertilizer Levels :

The oil content of safflower grain was decreased gradually with increased levels of fertilizer application. The highest oil content of 29.82 per cent was observed due to application of lowest level of fertilizer (25 kg N + 12.5 kg P_2O_5/ha).

Plant Densities :

The oil content of safflower grain was not affected much due to different plant densities; however, it was slightly decreased with decreased levels of plant densities.

4.8.2 Protein content :

Data presented in Table 18 revealed that the mean protein content in safflower grain was 16.04 per cent.

Table 18 : Mean oil and protein content in grain as affected by various treatments

Treatments	Oil content (per cent)	Protein content (per cent)
Fertilizers (kg/ha)		
$N + P_2O_5$		
25 + 12.5	29.87	15.07
50 + 25	29.53	15.78
75 + 37.5	28.72	16.48
100 + 50	28.12	16.96
Plant Densities (lakh/ha)		
2.25	29.34	16.26
1.50	29.30	16.08
1.00	29.28	15.84
0.75	29.26	15.83
General mean	29.17	16.04

Fertilizer Levels :

The protein content in grain was increased gradually with increased levels of fertilizer application. The maximum protein content of 16.96 per cent was recorded due to application of 100 kg N + 50 kg P_2O_5/ha.

Plant Densities :

The protein content in grain was slightly declined with decreased levels of plant densities. The minimum (15.83 per cent) and maximum (16.26 per cent) protein content was observed in plant densities of 0.75 and 2.25 lakh plants/ha, respectively.

5. DISCUSSION

5. DISCUSSION

The experimental findings of the investigation as given in the preceding chapter are discussed in this chapter.

5.1 Soil, Weather and Crop Development :

The analysis of the soil of the experimental plot at the commencement of present investigation showed that the soil under the experimental plot was clayey in texture. The studies on the initial status of the nutrient content indicated that the soil was low in available nitrogen, medium in available phosphorus and fairly rich in available potash content (Table 1). The soil was, thus, classed as medium in fertility on the basis of criteria laid down by Muhr et al. (1965). The soil was slightly alkaline in reaction and medium in depth. Thus, soil was appropriate for growing of safflower.

During the entire growth period of safflower, the mean maximum temperatures ranged between 28.1 to 35.0°C while the mean minimum temperatures ranged between 8.6 to 16.2°C. The mean relative humidity ranged between 69 to 93 per cent during the morning hours and 20 to 47 per cent during evening hours (Table 2). These conditions could be considered as normal for safflower crop. The rainfall of 110.4 mm in 3 rainy days was received during November. The aphid incidence increased due to this rainfall.

The experimental crop was sown on October 31, 1985. The crop had a mild attack of apnids during early crop growth stages and it increased during later stages. To minimise the attack of aphids, spraying of 0.07% endosulphan was done four times during the early stages and dusting of 10% BHC was done twice during the later stages.

To have a general idea about the nature of growth and development of safflower under the soil and enviromental conditions of Pune, the general mean of different growth attributes, yield contributing characters, yield and other attributes were studied. The general mean emerged from this study are presented in Table 19.

Table 19 : Influence of season on the performance of important characters of safflower

Characters	General mean
Initial plant stand	327.37
Final plant stand	319.89
Height of plant	109.18
Spread of plant	62.84
Number of main branches/plant ...	20.64
Number of sub-branches/plant ...	20.75
Totaldry matter (g)	66.08

Table 19 (contd.)

Characters		General mean
Number of capsules/plant	...	34.85
Number of grains/plant ...	...	354.98
Weight of grain/plant ...	...	20.23
1000 grain weight (g) ...	...	53.58
Grain yield (q/ha) ...	...	16.10
Bhusa yield (q/ha) ...	...	38.98
Harvest index ...	...	29.12
Nitrogen content (%) in grain	...	2.56
Nitrogen content (%) in bhusa	...	0.594
Phosphorus content (%) in grain	...	0.524
Phosphorus content (%) in bhusa	...	0.189
Nitrogen uptake (kg/ha) by grain	...	41.36
Nitrogen uptake (kg/ha) by bhusa		24.18
Total nitrogen uptake (kg/ha)		65.84
Phosphorus uptake (kg/ha) by grain		8.37
Phosphorus uptake (kg/ha) by bhusa		7.48
Total phosphorus uptake (kg/ha)	...	15.85
Oil content (%) in grain	...	29.17
Protein content (%) in grain	...	16.04

The mean initial plant stand after thinning and final plant stand at harvest was 327.37 and 319.89 plants/net plot, respectively (Table 19). The growth of the crop in terms of height and spread was 109.18 and 62.84 cm, respectively at harvest. The maximum number of main and sub-branches were 20.64 and 20.75, respectively at harvest. In safflower, branch number is one of the dominent factors which is responsible for yield because capsule number/plant and grain number/capsule depends upon the number of branches per plant. The total number of branches produced by a plant indicates the potentiality of a plant for growth, but from the production point of view, it is the number of flowers and capsules which turn productive by bearing filled capsules are very important.

The rate of dry matter accumulation was alow during early stages of crop growth upto 45 days after sowing. The rate of dry matter production/plant was rapid during the period between 45 to 90 days after sowing. The plant had produced 87.83 per cent of dry matter upto 90 days after sowing. The mean maximum dry matter accumulation per plant was 66.08 g at harvest.

Plant produced maximum height and spread during early stages upto 60 days after sowing. The plant had attained 90·68 per cent height and produced 64.11 per cent spread upto 60 days after sowing (Table 20). The plant had also produced 77.08 per cent of branches upto 60 days after sowing. The rapid expansion of these characters in the early part of the life of the crop was beneficial for dry matter production in terms of vegetative parts, which subsequently formed a base for dry matter accumulation in terms of reproductive parts.

The mean maximum number of capsules per plant was 34.85 at harvest. The mean number of grains and its weight per plant was 354.98 and 20.23 g respectively. The mean 1000 grain weight was 53.58 g. The safflower had produced 16.10 and 38.98 q/ha of grain and bhusa yields, respectively, with the mean harvest index of 29.12 (Table 19).

The grain and bhusa contained 2.566 and 0.594 per cent nitrogen and 0.524 and 0.189 per cent phosphorus, respectively. The safflower crop had removed 65.54 kg total nitrogenand 15.85 kg total phosphorus per hectare. The mean oil and protein content was 29.17 and 16.04 per cent, respectively.

It would be seen from the data in Table 20 that about 52.57 per cent of height was completed in 45 days after sowing. Thereafter, the plant height increased progressively and about 90.68 per cent of height attained in 60 days after sowing. The increase in plant spread was a faster during the early stages of crop growth and about 53.08 per cent of plant spread was completed in 45 days after sowing. Thereafter, the plant spread increased gradually and 76 per cent plant spread was completed upto 75 days. The main branches start after 45 days, whereas sub-branches started 60 days after sowing. The rate of main branch formation was rapid during early stages. About 77 per cent of main branches and 69 per cent of sub-branches were formed upto 60 days after sowing. The growth of main and sub-branches continued thereafter and 90 per cent of main and 86 per cent of sub-branches were formed in 90 days after sowing. The rate of dry matter accumulation was slow during early crop growth stages upto 45 days after sowing. The plant had produced 60 per cent of dry matter upto 60 days after sowing. The dry matter accumulation was progressively increased thereafter and 88 per cent of dry matter was accumulated in 90 days after sowing.

5.2 Effect of fertilizer levels :

The initial and final plant population (Table 7) was not influenced due to different levels of fertilizers. The growth rate in terms of plant height was slow upto rosette stage (Table 8). The application of 100 kg N + 50 kg P_2O_5/ha produced significantly more plant height over 25 kg N + 12.5 kg P_2O_5/ha and 50 kg N + 25 kg P_2O_5/ha at all the crop-growth stages except at 60 days after sowing and at harvest. The application 75 kg N + 37.5 kg P_2O_5/ha also increased plant height significantly over 25 kg N + 12.5 kg P_2O_5/ha during early crop growth stages viz., 30 and 45 days after sowing. Gilbert and Tucker (1967), Girase et al. (1976) and Mulik (1984) also reported increase in plant height with increased levels of nitrogen application. The application of higher levels of fertilizer were found to be on par with each other,

Table 20 : An extract of relevant information showing percentage of height, spread, number of main and sub-branches and dry matter per plant recorded periodically

Days after sowing	Plant height		Plant spread		Number of branches				Dry matter per plant	
					Main		Sub			
	Absoluate cm	% of the total	Absolute cm	% of the total	Absolute cm	% of the total	Absolute cm	% of the total	Absolute cm	% of the total
30	17.61	16.12	27.09	43.10	-	-	-	-	3.57	5.40
45	57.40	52.57	33.36	53.08	14.22	68.89	-	-	15.01	22.71
60	99.01	90.68	40.29	64.11	15.91	77.08	18.59	69.49	39.96	60.47
75	101.87	93.30	47.57	75.70	17.42	84.39	20.17	75.40	47.60	72.03
90	104.97	96.14	54.90	87.36	18.65	90.35	22.94	85.75	58.04	87.83
105	107.64	98.58	59.25	94.28	19.72	95.54	25.52	95.40	62.58	94.70
At harvest	109.18	100.00	62.84	100.00	20.64	100.00	26.75	100.00	66.08	100.00

however, they produced significantly more plant spread over lowest level of 25 kg N + 12.5 kg P_2O_5/ha at most of the crop growth stages. The increase in plant spread with increased levels of nitrogen application was also recorded by Girase et al. (1980), Mane and Narkhede (1982b) and Mulik (1984).

The main and sub-branches are important yiteld contributing characters in safflower. The application of 100 kg N + 50 kg P_2O_5/ha increased main and sub-branches per plant significantly over other fertilizer levels at all the crop growth stages except on 45 days after sowing and at harvest where main branches were on par with 75 kg N + 37.5 kg P_2O_5/ha. The application of 75 kg N + 37.5 kg P_2O_5/ha also increased number of main branches significantly over 25 kg N + 12.5 kg P_2O_5/ha on 45, 60, 75 and 90 days and sub-branches on 60 and 105 days after sowing and at harvest. Umrani et al. (1981) reported that application of 50 kg N/ha showed favourable influence on primary branches under dry land conditions; whereas, Mulik (1984) reported maximum number of primary and secondary branches due to application of 75 kg N/ha under irrigated conditions.

The increase in plant vigour in terms of plant height, spread and number of main and sub-branches with increased levels of fertilizers was found to be helpful in utilising the radient energy more effectively and thereby resulting in increased synthesis of carbohydrates. Hence, the general vigour of the plants fertilized with higher levels of N and

P increased. The application of 100 kg N + 50 kg P_2O_5/ha accumulated significantly more dry matter as compared to 25 kg N + 12.5 kg P_2O_5/ha and 50 kg N + 25 kg P_2O_5/ha on 45, 60, 75 days after sowing and at harvest (Table 12). The application of 75 kg N + 37.5 kg P_2O_5/ha also increased dry matter accmmulation per plant significantly over 25 kg N + 12.5 kg P_2O_5/ha on 45 and 60 days after sowing and at harvest. The plant receiving 75 kg N + 37.5 kg P_2O_5/ha and 100 kg N + 50 kg P_2O_5/ha accumulated 66.94 and 68.61 g of dry matter as compared to 63.75 g due to application of 25 kg N + 12.5 kg P_2O_5/ha. The plant fertilized with these higher levels of fertilizers increased dry matter production considerably and consequently resulted in the production of more grain yield. Sheelavantar (1973) observed that dry matter production was increased due to nitrogen application upto 40 kg/ha under dry land conditions; whereas, Mulik (1984) recorded maximum dry matter accumulation with application of 75 kg N/ha under irrigated conditions.

The capsule number per plant is an important yield contributing character in safflower. The application of 75 kg N + 37.5 kg P_2O_5/ha and 100 kg N + 50 kg P_2O_5/ha increased number of capsules significantly over 25 kg N + 12.5 kg P_2O_5/ha and 50 kg N + 25 kg P_2O_5/ha at harvest (Table 13). The results corroborate the findings of Mulik (1984). The number of grains per plant were not differed significantly. However, the beneficial increase in number of grains/plant was observed with increased levels of fertilizer application. The weight of grains/plant decreased significantly due to application of 25 kg N + 12.5 kg P_2O_5/ha as compared to higher fertilizer levels which were on par with each other (Table 14). The increase in grain weight/plant with higher levels of fertilizer application resulted in translocation of more photosynthates in to capsule which increased its sink capacity resulting in higher yields

Similar findings were reported by Mulik (1984). The application of higher levels of fertilizer viz., 75 kg N + 37.5 kg P_2O_5/ha and 100 kg N + 50 kg P_2O_5/ha increased 1000 grain weight significantly over 25 kg N + 12.5 kg P_2O_5/ha. The results are inconformity with the findings of Sounda et al. (1977) and Mane and Narkhede (1982).

The applications of 75 kg N + 37.5 kg P_2O_5/ha and 100 kgN+ 50 kg P_2O_5/ha were found to be on par but increased grain yield significantly over 50 kg N + 25 kg P_2O_5/ha and 25 kg N + 12.5 kg P_2O_5/ha (Table 15). The grain yield increased by 7.29, 20.81 and 22.85 per cent due to application of 50 kg N + 25 kg P_2O_5/ha, 75 kg N + 37.5 kg P_2O_5/ha and 100 kg N + 50 kg P_2O_5/ha, respectively, over lowest level of 25 kg N + 12.5 kg P_2O_5/ha. The important yield attributing characters like, number of main and sub-branches, dry matter accumulation, number of capsules, number of grains and its weight per plant and 1000 grain weight were favourably influenced with increased levels of fertilizer application.

This resulted in increased grain yield with higher levels of fertilizer application. These results corroborate the findings of Anomymous (1976), Sounda et al. (1977), Singh and Singh (1980), Mane and Narkhede (1982a) and Mulik (1984).

The application of 100 kg N + 50 kg P_2O_5/ha, 75 kg N + 37.5 kg P_2O_5/ha were on par; however, increased bhusa yield significantly over 50 kg N + 25 kg P_2O_5/ha and 25 kg N + 12.5 kg P_2O_5/ha. Further, it was noticed that the application of 50 kg N + 25 kg P_2O_5/ha also produced significantly more bhusa yield over 25 kg N + 12.5 kg P_2O_5/ha (Table 15). The bhusa yield was increased by 22.22, 28.98 and 32.96 per cent due to application of 50 kg N + 25 kg P_2O_5/ha, 75 kg N + 37.5 kg P_2O_5/ha and 100 kg N + 50 kg P_2O_5/ha, respectively, over 25 kg N + 12.5 kg P_2O_5/ha. The increase in bhusa yield with higher levels of fertilizers was due to increased plant height, spread and main and sub-branches per plant. Similar findings were reported by Mulik (1984).

The maximum harvest index (30.62) was recorded due to application of 25 kg N + 12.5 kg P_2O_5/ha followed by application of 75 kg N + 37.5 kg P_2O_5/ha, whereas the harvest index was 29.26.

It was interesting to note the relationship of added nitrogen and phosphorus fertilization and production of irrigated safflower. A second degree quadratic equation was fitted to the yield data (Fig.8).

$$Y = 12.225 + 0.05623 x - 0.000133 x^2$$

The optimum dose of nitrogen and phosphorus was estimated as 120.79 kg N + 59.49 kg P_2O_5/ha which falls out of the range tried under experimentation. The estimated production of safflower at this optimum dose was 18.04 q/ha. R^2 value was 0.9570 which showed good fit of response equation.

The maximum benefit cost ratio of 6.80 was recorded with the application of 25 kg N + 12.5 kg P_2O_5/ha. Therefore, atleast this much fertilizer dose should be applied, without leaving unfertilized crop (Table 21). Further, it was noticed that the maximum additional returns of Rs.3180/ha were recorded due to application of 100 kg N + 50 kg P_2O_5/ha. However, the maximum additional net returns of Rs.2466/ha with a benefit cost ratio of 5.57 were obtained with the application of 75 kg N + 37.5 kg P_2O_5/ha. It would be, therefore, better to fertilize irrigated safflower with 75 kg N + 37.5 kg P_2O_5/ha.

The nitrogen and phosphorus content in grain and <u>bhusa</u> progressively increased with increased levels of fertilizer application (Table 16). The results are inconformity with the findings of Jones and Tucker (1968), Singh and Singh (1980), Haby *et al*. (1982) and Mulik (1984).

The uptake of nitrogen and phosphorus by grain and <u>bhusa</u> and total uptake of these nutrients was also increased

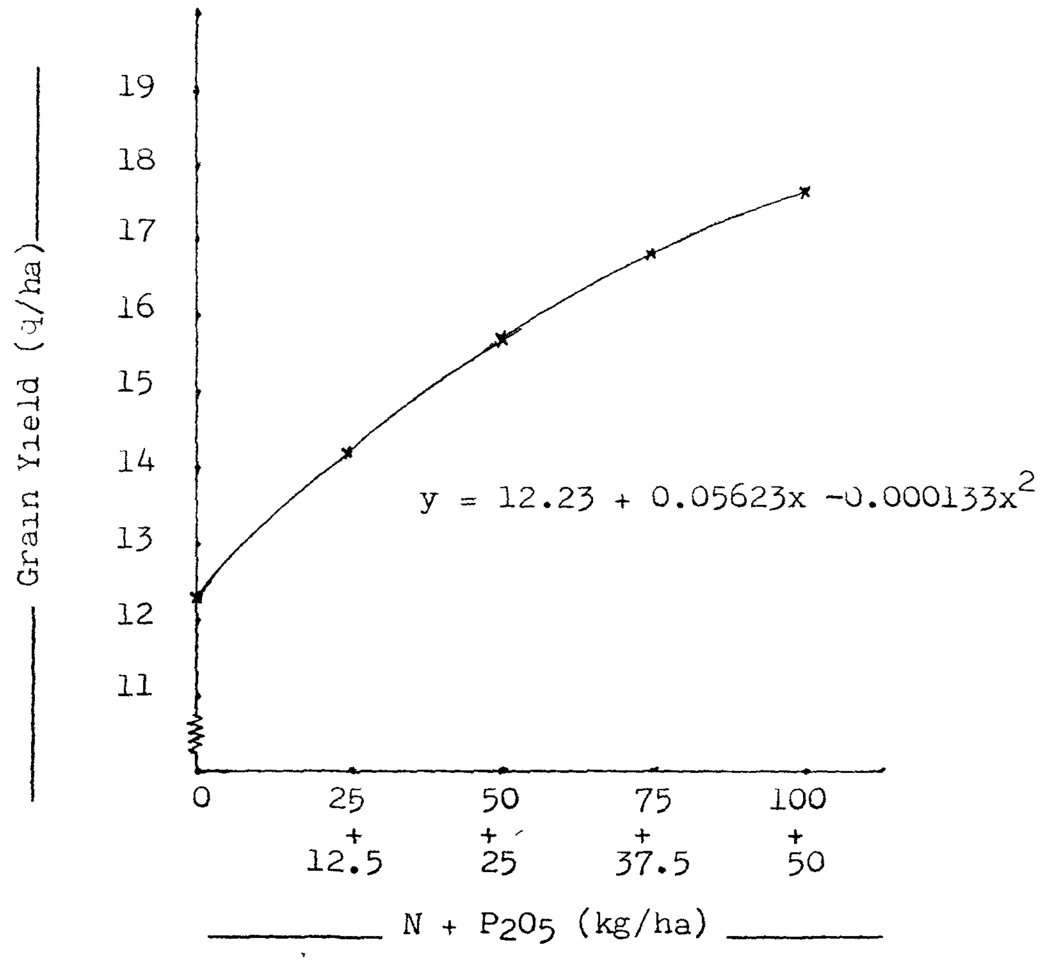


Fig.8 Response of irrigated safflower to nitrogen and phosphate fertilization

Table 21 : Economics of nitrogen and phosphate fertilization to safflower

$N + P_2O_5$ (kg/ha)	Grain yield (q/ha)	Additional yield over control (q/ha)	Additional response/kg of $N+P_2O_5$ over control (kg/ha)	Value of nutrients (Rs/ha)	Price of additional yield over control (Rs/ha)	Addil.Net returns over control (Rs/ha)	Benefit cost ratio
0*	12.23	-	-	-	-	-	-
25 + 12.5	14.27	2.04	5.44	179.88	1224.00	1044.12	6.80
50 + 25	15.31	3.08	4.11	359.75	1848.00	1488.25	5.13
75 + 37.5	17.24	5.01	4.45	539.63	3006.00	2466.37	5.57
100 + 50	17.53	5.30	3.53	719.50	3180.00	2460.5	4.52

* = Estimated with regression equation

Cost of N = Rs.4.46/kg, cost of P_2O_5 = 5.47/kg. Price of safflower grain = Rs.600/q.

progressively with increased levels of fertilizer application (Table 17). The increase in grain and <u>bhusa</u> yield and concentration of nitrogen and phosphorus in grain and <u>bhusa</u> due to increased levels of fertilizer application resulted in increased uptake of these nutrients. Jones and Tucker (1968), Singh and Singh (1980), Haby *et al.* (1982) and Mulik (1984) also reported that increased levels of nitrogen application increased uptake of N, P and K.

The oil content of safflower decreased gradually with increased levels of fertilizer application (Table 16). The oil content was maximum (29.87 per cent) due to application of 25 kg N + 12.5 kg P_2O_5/ha. These results were based on mean values only, however, corroborate the findings of Girase *et al.* (1980), Eveida *et al.* (1981), Haby *et al.* (1982) and Mulik (1984).

The protein content in safflower grain was increased progressively with increased levels of fertilizer application. The protein content was maximum (16.96 per cent) with application of 100 kg N + 50 kg P_2O_5/ha. Haby *et al.* (1982), Mane and Narkhede (1982a) and Mulik (1984) also reported that the protein content in grain was increased with increased levels of fertilizer application.

5.3 Effect of Plant Densities :

The number of plants per net plot was increased significantly with increased levels of plant densities at initial stage as well as at harvest. The plant density per unit area is a base of yield trangle which was favourably influenced with increased levels of plant densities resulting in increased grain and <u>bhusa</u> yields.

The higher plant densities of 2.25 and 1.50 lakh plant/ha produced significantly more plant height over the plant densities of 0.75 and 1.00 lakh plants/ha from 45 to 105 days after sowing (Table 8). Whereas, it was increased significantly with increased levels of plant densities at harvest. This might be due to severe intra-row competition resulting in lanky appearance of the plant. The other reasons may be that there was reduction in the number of main branches causing translocation of photosynthates to only growing bud. This is evident from the data on dry matter accumulation wherein lower plant density had higher rate of dry matter/plant compared to that of higher plant density/unit area. The plant densities of 0.75 and 1.00 lakh plants/ha produced significantly more plant spread than the higher plant densities of 1.50 and 2.25 lakh plants/ha at all the crop growth stages (Table 9). Similar findings were reported by Nasar et al.(1978), Girase et al.(1980), Mane and Narkhede (1982 b) and Mulik (1984).

The lower plant densities of 0.75 and 1.0 lakh plants/ha increased number of main branches significantly over higher plant densities of 1.50 and 2.25 lakh plants/ha on 45 and 75 days after sowing and number of sub-branches on 60 days after sowing (Tables 10 and 11). Further, it was noticed that the number of main-branches were significantly increased with the plant density of 0.75 lakh plants/ha and significantly decreased with 2.25 lakh plants/ha on 60 days after sowing. Kulandalvelu et al. (1974) and Girase et al. (1980) reported highest number of primary and secondary branches with lowest plant density.

The dry matter accumulation/plant was significantly more with the plant density of 0.75 lakh plants/ha as compared to plant densities of 1.50 and 2.25 lakh plants/ha at all the crop growth stages (Table 12). Further, it was observed that the plant density of 1.00 lakh plants/ha accumulated more dry matter/plant over the plant density of 2.25 lakh plants/ha at all the crop growth stages except on 30 days after sowing.

The number of capsules/plant decreased with the higher plant density of 2.25 lakh plants/ha as compared to lower plant densities on 90 days after sowing and at harvest (Table 13). The number of grains/plant and 1000 grain weight were increased significantly with decreased levels of plant densities. The grain weight/plant was significantly reduced with highest plant density of 2.25 lakh plants/ha than lower plant densities (Table 14). Hoag et al. (1968), Abel (1978), Girase et al. (1980), Mane and Narkhede (1982a) and Mulik (1984) also reported that high plant population produce fewer heads/plant, fewer seeds/head and smaller seed than low population.

The grain and bhusa yields were significantly increased with increased levels of plant densities. The plant densities of 2.25, 1.50 and 1.00 lakh plants/ha increased grain yield by 78.84, 57.46 and 30.38 per cent, respectively, over plant density of 0.75 lakh plants/ha. Whereas, the plantdensities of 2.25, 1.50 and 1.00 lakh plants/ha increased bhusa yield by 30.63, 20.95 and 7.12 per cent, respectively, over the plant density of 0.75 lakh plants/ha (Table 15). Thus, grain and bhusa yields were linearly related with the plant density. The linear yield-plant density of relationship in this investigation exists because the additional number of plants in high plant density compensated for the loss in yield that could otherwise have occurred owing to a reduction in the yield components under high plant density. The results are inconformity with the findings of Beech and Norman (1966), Montilla (1968), Kulandaivelu et al. (1974), Nasar et al. (1978), Singh and Yusuf (1979) and Mulik (1984).

The harvest index was increased gradually with increased levels of plant densities. Donald and Hamblin (1976) reported increase in harvest index with increased plant densities.

The nitrogen and phosphorus contents in grain and Bhusa were increased gradually with increased levels of plant densities (Table 16). Mulik (1984) also reported increase in nitrogen and phosphorus content in grain and bhusa with increased plant densities.

The nitrogen and phosphorus uptake by grain and bhusa and total uptake of these nutrients was increased progressively with increased levels of plant densities (Table 17). This was attributed to the higher grain and bhusa yields and more nitrogen and phosphorus content in grain and bhusa.

Similar findings were reported by Mane (1976) and Mulik (1984).

The oil and protein content which are important quality attributes in safflower were declined slightly with decreased levels of plant densities (Table 18). The maximum oil (29.34 per cent) and protein (16.26 per cent) content were recorded under the plant density of 2.25 lakh plants/ha. The results corroborate the findings of Mulik (1984).

5.4 Effect of Interaction :

Interaction effects between fertilizer levels and plant densities were found to be absent in respect of growth and yield attributing characters, yields and nutrient uptake.

6. SUMMARY AND CONCLUSIONS

6. SUMMARY AND CONCLUSIONS

6.1 SUMMARY :

The field investigation on the "Effect of Nitrogen, Phosphorus Levels and Plant Densities on the Growth, Yield and Quality of Irrigated Safflower" on variety Bhima of safflower was carried out during rabi season of 1985-86 at the Agricultural College Farm, Pune (Maharashtra).

The experiment was laid out in factorial randomised block design with four levels of fertilizers and plant densities replicated three times.

The soil of the experimental plot was clayey in texture, low in available nitrogen, medium in available phosphorus and fairly rich in available potash. It was slightly alkaline in reaction.

There were four fertilizer levels viz., 25 kg N + 12.5 kg P_2O_5/ha, 50 kg N + 25 kg P_2O_5/ha, 75 kg N + 37.5 kg P_2O_5/ha and 100 kg N + 50 kg P_2O_5/ha and four plant densities viz., 2.25 lakh plants/ha (45 x 10 cm), 1.50 lakh plants/ha (45 x 15)cm, 1.00 lakh plants/ha (45.x 22.5 cm), and 0.75 lakh plants/ha (45 x 30 cm). The gross and net plot sizes were 6.30 x 5.40 M^2 and 5.40 x 4.50 M^2, respectively. The crop was dibbled on October 31, 1985 at the spacing as per treatments. The cultural operations and plant protection measures were carried out on time. The season, in general, was good for the growth and development of safflower.

Besides grain and bhusa yields the observations on periodical growth attributes and yield contributing characters were also recorded. The chemical analysis for estimation of N and P in grain and bhusa was carried out. The uptake of these nutrients was worked out. The oil content in grain was estimated. The protein content was also worked out.

6.1.1 Effect of fertilizer levels :

The application of 100 kg N + 50 kg P_2O_5/ha produced significantly more plant height and spread over 25 kg N + 12.5 kg P_2O_5/ha and 50 kg N + 25 kg P_2O_5/ha at most of the crop growth stages. The plant receiving 100 kg N + 50 kg P_2O_5/ha showed significant improvement in main and sub-branches per plant. The application of 75 kg N + 37.5 kg P_2O_5/ha also increased number of main brancnes significantly over 25 kg N + 12.5 kg P_2O_5/ha at most of the crop growth stages. Plants fertilized with 100 kg N + 50 kg P_2O_5/ha accumulated significantly more dry matter than 25 kg N + 12.5 kg P_2O_5/ha and 50 kg N + 25 kg P_2O_5/ha.

The application of 75 kg N + 37.5 kg P_2O_5/ha and 100 kg N + 50 kg P_2O_5/ha increased number of capsules per plant significantly over 25 kg N + 12.5 kg P_2O_5/ha and 50 kg N + 25 kg P_2O_5/ha at harvest. The beneficial increase in number of grains and its weight/plant and 1000 grain weight was also observed with increased levels of fertilizer application.

The application of 75 kg N + 37.5 kg P_2O_5/ha and 100 kg N + 50 kg P_2O_5/ha were on par but increased grain and bhusa yield significantly over 50 kg N + 25 kg P_2O_5/ha and 25 kg N + 12.5 kg P_2O_5/ha. The grain yield was increased by 7.29, 20.81 and 22.85 per cent due to application of 50 kg N + 25 kg P_2O_5/ha, 75 kg N + 37.5 kg P_2O_5/ha and 100 kg N + 50 kg P_2O_5/ha, respectively, over the 25 kg N + 12.5 kg P_2O_5/ .

The maximum additional net returns of Rs.2466/ha with benefit cost ratio of 5.57 was obtained due to application of 75 kg N + 37.5 kg P_2O_5/ha. Therefore, it would be advisible to fertilize safflower with 75 kg N + 37.5 kg P_2O_5/ha under irrigated conditions.

The nitrogen and phosphorus content in grain and bhusa and uptake of nitrogen and phosphorus by grain and bhusa and total uptake of these nutrients increased progressively with increased levels of fertilizer application.

The oil content in grain was decreased gradually with increased levels of fertilizers, whereas, the protein content was increased progressively with increased levels of fertilizers.

6.1.2 Effect of plant densities :

The number of plants/net plot was increased significantly with increased levels of plant densities at initial stage as well as at harvest.

The higher plant densities of 2.25 and 1.50 lakh plants/ha produced significantly more plant height, whereas the plant spread and number of main and sub-branches were decreased with increased levels of plant densities. The dry matter accumulation/plant was significantly more with the plant density of 0.75 lakh plants/ha as compared to 1.50 and 2.25 lakh plants/ha at all the crop growth stages.

The number of capsules/plant, number of grains and its weight/plant and 1000 grain weight showed beneficial improvement with decreased levels of plant densities.

The grain and bhusa yields were significantly increased with increased levels of plant densities. The plant densities of 2.25, 1.50 and 1.00 lakh plants/ha increased grain yield by 78.84, 57.46 and 30.38 per cent, respectively, over the plant density of 0.75 lakh plants/ha. Therefore, the plant density of 2.25 lakh plant/ha was optimum for irrigated safflower.

The nitrogen and phosphorus content in grain and bhusa and uptake of these nutrients by grain and bhusa and total uptake was increased progressively with increased levels of plant densities.

The oil and protein content in grain were declined slightly with decreased levels of plant densities.

6.1.3 Effect of interaction :

The interaction effects between fertilizer levels and plant densities were not present.

6.2 CONCLUSIONS :

(1) The application of 100 kg N + 50 kg P_2O_5/ha gave maximum additional returns of Rs.3180/ha. However, the highest additional net returns of Rs.2466/ha with benefit cost ratie of 5.57 was recorded with 75 kg N + 37.5 kg P_2O_5/ha. It is, therefore, suggested to fertilizer irrigated safflower with 75 kg N + 37.5 kg P_2O_5/ha.

(2) The plant density of 2.25 lakh plants/ha gave highest grain and bhusa yield and harvest index. Therefore, this plant population could be considered optimum for irrigated safflower.

The above conclusions, however, are based on a single year's results. Therefore, for confirmation of these results, the investigation needs to be repeated.

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8. VITA

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A. T. POWAR

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of

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