STUDIES ON THE EFFECT OF PHOSPHORUS AND BORON ON THE YIELD AND SEED SETTING OF SUNFLOWER (*Helianthus annuus* L.)

Thesis submitted in part fulfilment of the requirements for the degree of **Master of science** (Agriculture) in **Agronomy** to the Tamil Nadu Agricultural University, Coimbatore - 641 003.

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1996

CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON THE EFFECT OF PHOSPHORUS AND BORON ON THE YIELD AND SEED SETTING OF SUNFLOWER *(Helianthus annuus* L.)"** submitted in part fulfilment of the requirement for the degree of **MASTER OF SCIENCE (AGRICULTURE) IN AGRONOMY** to the Tamil Nadu Agricultural University, Coimbatore is a record of **bonafide** research work carried out by **Miss.C.SUSHEELA** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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Date : 21.6.96

EXTERNAL EXAMINER

Dedicated

to my

Beloved Parents

ACKNOWLEDGEMENT

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I give all the glory to my Lord God Almighty for giving me His strength and grace to complete this work successfully.

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ABSTRACT

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STUDIES ON THE EFFECT OF PHOSPHORUS AND BORON ON THE YIELD AND SEED SETTING OF SUNFLOWER (*Helianthus annuus* L.)

By

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Degree : **Master of Science (Agriculture) in Agronomy**

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(1996

Field experiments were conducted at Tamil Nadu Agricultural University Farm, Coimbatore during **Rabi**'94 and **Kharif**, '95 to study the effect of different levels of phosphorus and foliar application of diammonium phosphate and borax on yield and seed setting of sunflower hybrid MSFH-8 under irrigated conditions.

The experiments were laid out in a factorial randomised block design with two factors with four levels each. Different levels of phosphorus (0, 30, 60 and 90 kg P_2O_5 ha^{-1}) and different foliar spraying treatments **viz**., no spray (control), 2 per cent DAP spray, 0.2 per cent borax spray, 2 per cent DAP + 0.2 per cent borax combined spray.

Phosphorus application had influenced the growth characters like plant height, LAI and dry matter production.

Application of 90 kg P_2O_5 ha^{-1} recorded higher LAI and DMP followed by 60 kg P_2O_5 ha^{-1}. Yield components like diameter of the head, number of seeds per head, percentage of filled seeds and test weight were also significantly influenced by phosphorus application. Seed yield was high at 90 kg P_2O_5 ha^{-1} which is at par with that at 60 kg P_2O_5 ha^{-1}. There was a favourable influence on oil content due to phosphorus application.

Nutrient uptake was also increased by the application of phosphorus. Phosphorus application did not exert significant influence on soil available N and K. Soil available P content was increased with increasing levels of phosphorus application.

Foliar spraying of 2 per cent DAP and 0.2 per cent borax showed no significant influence on the growth parameters and yield components like diameter of the head and test weight. Foliar application of DAP at 2 per cent and borax at 0.2 per cent had favourably influenced the number of seeds per head and seed filling percentage. Oil content was not significantly influenced by spraying of DAP and borax.

In general, **Rabi** season crop performed better than **Kharif** season crop.

Net return and B:C ratio were higher with 60 kg P_2O_5 ha^{-1} + 2 per cent DAP and 0.2 per cent borax combined spray.

To summarise the results of the study, application of 60 kg P_2O_5 ha^{-1} along with foliar spraying of 2 per cent DAP and 0.2 per cent borax was found to be remunerative in hybrid sunflower MSFH-8.

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CHAPTER I

INTRODUCTION

Oil seeds play an important role in the day to day life. Oil seeds are sources of energy in human nutrition. The main product of oil seeds is oil which finds uses as food fat and also as industrial raw material for development of various oleochemicals.

India holds a premier position in the world in terms of rich diversity of oil seed crops and also in the area of their cultivation. During 1994-95, in India, the area under oil seeds was 26 million hectares, production was 22.5 million tonnes and productivity was 865 kg ha^{-1}. Although India has 20.8 per cent of the world's area under oil seeds, it accounts for less than 10 per cent of world's production. Oil seeds form the second largest agricultural commodity after cereals in India sharing 13 per cent of the country's gross cropped area accounting for nearly five per cent of gross national product (GNP).

In Tamil Nadu, oil seeds occupy an area of about 14.76 lakh hectares with the production of 20.33 lakh tonnes. The productivity of oil seeds is 1377 kg ha^{-1} in Tamil Nadu.

Sunflower is an important oil seed crop in the world and ranks third next to cotton seed and groundnut in the total world production of oil seed. In terms of area,

India ranks third in sunflower. During 1994-95, production of sunflower in India was 11.8 lakh tonnes. Karnataka state leads in both area and production followed by Maharashtra. The area, production and productivity of sunflower in Tamil Nadu are 0.57 lakh hectares, 0.45 lakh tonnes and 789 kg ha^{-1} respectively.

Now sunflower crop is widely accepted by Indian farmers because of its desirable attributes such as low seed rate, high seed multiplication ratio (1 to 100), short duration, photoinsensitivity and higher water use efficiency. Sunflower oil which contains a high proportion of poly-unsaturated fatty acids and do not contribute to increased blood cholesterol levels greatly.)

The most important problem associated with sunflower cultivation is the occurrence of poorly filled or hollow seeds. This may be due to inadequacy of insect pollinators, nutrient deficiency, inbreeding depression, self-incompatibility and rains during the blooming period which causes washing off of pollen.

In plants, phosphorus is involved in energy storage and transfer. Phosphorus is also an important structural component of nucleic acids, coenzymes, nucleotides, phosphoproteins, phospholipids and sugar phosphates. Phosphorus plays an important role in carbohydrate metabolism and helps in the conversion of carbohydrates into oil. (Bonner and Varner, 1965).

Phosphorus is also considered essential for seed formation. An adequate supply of P early in the life of a plant is important in the development of its reproductive parts.

Generally phosphate fertilizers applied as basal get fixed in soil and rendered unavailable to plants. Foliar sprays enable better absorption and ensure economic utilization of applied fertilizers. Foliar spraying of DAP is reported to be beneficial in several crops.

Among micronutrients, boron is stated to influence many growth parameters and filling up of seeds. (Blamey, 1976). Boron helps in pollen germination and increases pollen viability and fertilization.. So it was felt necessary to study the effect of phosphorus application, DAP and borax spraying in influencing the growth and yield attributes of sunflower.

Studies on nutrient management of sunflower hybrids being limited, this study was attempted with the following objectives.

1. To study the influence of varied levels of P on the productivity of sunflower.

2. To study the effect of foliar applied DAP and borax on seed set and seed filling of sunflower.

3. To identify efficient and economic level of P application and foliar spraying in sunflower.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Introduction of sunflower into India as an edible oilseed crop is of very recent origin. Being a newly introduced crop in this country, very little work has been done on the adaptability of this crop. Further attempts are being made constantly to design a suitable set of cultivation practices to realise the maximum output from sunflower. In the present study, attempts were made to study the effect of soil and foliar application of phosphorus and foliar application of boron on the performance of sunflower. The available literature on the above mentioned aspects are briefly reviewed in this chapter.

2.1. Effect of phosphorus

2.1.1. Effect of phosphorus on growth attributes

Vegetative growth is a measure of response of crops to various management practices particularly nutrients. The phosphorus starvation retarded the growth of the crop at every stage of its life cycle. With the possible exception of nitrogen, no other element has been as critical in growth of plants as phosphorus (Mitsui, 1970).. Cernea and Taran (1971) reported that N and P applied at sowing increased the number of leaves per plant and a split application of NPK, half at sowing and half at heading led to vigorous vegetative growth in sunflower. Mukundan (1972) found that application of phosphorus increased the plant

height, girth of the stem, drymatter of the plant and diameter of the capitulum.

Varghese **et al**. (1976a) reported that P application recorded high leaf area index at all stages of observation. The rate of drymatter accumulation was maximum (1.56 g plant^{-1} day^{-1}) at the highest fertility level of 80 N + 100 P_2O_5 + 40 K_2O kg ha^{-1} and minimum (1.41 g plant^{-1} day^{-1}) at the lowest fertility level. (40 N + 60 P_2O_5 + 40 K_2O kg ha^{-1}) (Srinivas and Patil 1977). Somasundaram and Iruthayaraj (1979) observed significant influence of P levels on leaf area index (LAI) and crop growth rate (CGR) but the effect on net assimilation rate (NAR) and relative growth rate (RGR) was not significant.

EL-Sayed **et al**. (1984) reported that plant height and stem diameter were increased with the increase in P application. Significant increase in plant height with the application of 80 kg of P_2O_5 ha^{-1} was observed by Chaniara **et al**. (1989).

Dravid (1989) reported that application of diammonium phosphate (DAP) was better than single super phosphate (SSP) and ammonium phosphate nitrate with respect to drymatter yield. Kandalkar **et al**. (1991) reported that growth attributes of sunflower were not affected with various levels of P but according to Naphade and Naphade (1991) and Ateeque and Malewar (1992) drymatter production and root length were significantly influenced by the

increased levels of P. Khokani **et al**. (1993) reported that P had no significant effect on growth attributes.

Every increment of P dose gave significant increase in drymatter yield of sunflower. The progressive response of DMP to added P was associated with the very low P availability in the soil (Ateeque **et al**., 1993). Bhowmik **et al**. (1994) reported that application of 40 kg P_2O_5 ha^{-1} improved growth attributes in Gangetic alluvial soil.

Application of P to the soils varying from low to high in available P content, increased dry matter yield (Balwinder Singh and Bishnoi, 1994).

From the above literature, it is clear that application of P influences the plant height, LAI, girth of the stem, DMP and CGR.

2.1.2. Effect of phosphorus on yield attributes

Nutrient management directly influences the growth of crops and consequently results in variation in yield attributes of crops . Shivakumar **et al**. (1973) reported that 25 per cent increase in grain yield with 30 kg P_2O_5 ha^{-1} compared to no P application was due to the increase in number of seeds per head and 100 seed weight. Singh and Kaushal (1975) recorded an increase of 16.8 per cent in 100 seed weight and 22.0 per cent in per plant yield with 60 kg P_2O_5 ha^{-1} over no P application in addition to reducing the percentage of unfilled seeds.

Varghese **et al**. (1976b) found that application of P exerted no significant effect on the diameter of head, number of seeds per head and number of filled seeds per head except thousand seed weight at 60 kg P_2O_5 ha^{-1}. Singh **et al**. (1977) reported that P application did not affect the head diameter, test weight and percentage of filled seeds significantly.

Soliman **et al**. (1981) found significant increase in head diameter and hundred seed weight with increasing levels of P. Rao and Reddy (1985) reported that thousand seed weight was significantly increased with the increase in levels of P. According to Shelke **et al**. (1988) there was no significant effect of applied phosphate in increasing thousand seed weight.

Number of seeds per head was significantly increased upto 80 kg P_2O_5 ha^{-1} whereas, head diameter and seed weight per head were increased only upto 60 kg P_2O_5 ha^{-1} (Chaniara **et al**., 1989). Ujjinaiah **et al**. (1989) reported that the diameter of capitulum, number of filled seeds per capitulum and thousand seed weight were found to be significantly differing between low (40 kg P_2O_5 ha^{-1}) and high (80 kg P_2O_5 ha^{-1}) levels of P application.

Megur **et al**. (1993) found increased number of filled grains and total number of grain and reduced per cent

of unfilled seeds with increased application of P upto 120 kg P_2O_5 ha^{-1}. Application of 40 kg P_2O_5 ha^{-1} improved yield attributes in Gangetic alluvial soil (Bhowmik **et al.**, 1994).

2.1.3. Yield

Sunflower being an oilseed crop responds well with different levels of P at various locations. Gaur **et al.** (1973) reported that among the four levels of P (0, 25, 50 and 75 Kg P_2O_5 ha^{-1}), seed yield increased progressively with increasing doses of P, however the differences between 50 and 75 kg P_2O_5 ha^{-1} were not significant. On the contrary Girase **et al.** (1975) and Varghese **et al.** (1976b) reported that there was no significant effect on the application of P on the yield of sunflower.

Gangwar and Parameswaran (1976) reported 41 to 48 per cent of seed yield response in sunflower to P application. Chaudhari **et al.** (1978) recorded significantly higher seed yield with 120 kg P_2O_5 ha^{-1} than at lower levels. Gowda **et al.** (1979) evaluated different levels of P from 30 to 90 kg P_2O_5 ha^{-1} and found that application of 90 kg P_2O_5 ha^{-1} recorded the highest seed yield in sunflower. Similar findings were also reported by Naphade and Naphade (1992).

Blamey and Chapman (1981) reported that there was significant seed yield response to N and P. The response was more to N when applied in combination with P than in the

absence of P fertilization. Singhi and Pacheria (1981) observed no response to applied P upto 60 kg P_2O_5 ha^{-1} when there was more soil available P. Sunflower seed yield was increased from 1.4 to 1.55 t ha^{-1} by the application of 45 kg P_2O_5 ha^{-1} and there was no significant yield increase to higher P application beyond 45 kg P_2O_5 ha^{-1} (Habeebullah **et al.**, 1986; Shelke **et al.**, 1988). Gaur **et al.** (1987) reported that the yield of sunflower was increased from 1.08 to 1.12 t ha^{-1} with 25 kg P_2O_5 ha^{-1} and no further increase was seen for additional dose of P.

Chaniara **et al.** (1989) obtained higher seed yields with 40, 60 and 80 kg P_2O_5 ha^{-1} but it was a non-significant trend of response to applied P but according to Ujjinaiah **et al.** (1989) significant difference in seed yield was obtained between lowest (40:40 kg ha^{-1}) and highest level (80:80 kg ha^{-1}) of N and P_2O_5 application. The maximum seed yield of 1591 kg ha^{-1} was obtained in highest level as compared to 1165 kg ha^{-1} in the lowest level of fertilizer application.

Loubser **et al.** (1990) reported that 10 mg kg^{-1} of soil extractable P was sufficient for obtaining seed yield upto 2 t ha^{-1} in sunflower. Sunflower did not respond to P levels upto 120 kg ha^{-1} (Sidhu **et al.**, 1991). Lewis **et al.** (1991) reported that at maximum seed yield, the critical nutrient range for soil extractable P and K were 16 to 20 mg kg^{-1} and 70 to 80 mg kg^{-1} respectively.

Thosar **et al**. (1991) reported that mean seed yield of sunflower increased upto 90 kg P_2O_5 ha^{-1}. Application of 40, 60 and 80 kg P_2O_5 ha^{-1} increased seed yield by 40.56, 74.71 and 79.62 per cent respectively over control (Naphade and Naphade, 1992).

Muralidharudu and Reddy (1992) concluded that increased levels of P resulted in higher seed yield and application of 60 kg P_2O_5 ha^{-1} recorded the highest seed yield of 1497 kg ha^{-1} as against 1136 kg ha^{-1} with no P application and they have identified that 60.8 kg P_2O_5 ha^{-1} was the optimum dose for sunflower.

The seed yield of sunflower was significantly increased with increasing levels of P and varied between 9.64 and 12.51 q ha^{-1} (Ateeque **et al**., 1993). Megur **et al**. (1993) found that the seed yield showed a significant increasing trend with additional doses of P from 30 to 120 kg P_2O_5 ha^{-1}. Vivek **et al**. (1993) reported that application of phosphorus increased the seed yield of sunflower significantly when 90 kg P_2O_5 ha^{-1} was applied as compared with control. A dose of 60 kg P_2O_5 ha^{-1} produced significantly more yield over 30 and 90 kg P_2O_5 ha^{-1} (Keneet **al**., 1993). Nandhagopal **et al**. (1995) reported 60 kg P_2O_5 ha^{-1} as optimum dose to get maximum yield in sunflower hybrid MSFH-17.

2.1.4. Effect of phosphorus on quality parameters

Phosphorus increases the oil yield and quality to a considerable extent. Gangwar and Parameswaran (1976) reported that the oil content of sunflower seed was significantly increased with increase in P levels from 0 to 60 kg ha^{-1} whereas, no significant effect on oil content was noticed by Varghese **et al**. (1976b) and Lewis **et al**. (1991). Tomov (1976) found that application of 100 to 200 kg P_2O_5 ha^{-1} increased the oil content, percentage of linoleic and unsaturated acids and oil yield. Protein content in sunflower seed was increased by N but decreased by P fertilization, but the oil content showed reverse response (Blamey and Chapman, 1981).

Chaudhary and Paturde (1981) concluded that seed oil content increased by application of phosphorus. Similar findings of better oil yield with P application was reported by Rao and Reddy (1985). Ujjinaiah **et al**. (1989) reported that oil content decreased from 39.7 to 36.9 per cent with the increased rate of P from 40 to 80 kg ha^{-1}.

Sidhu **et al**. (1991) found that the seed protein content increased with N and P application and seed oil content decreased with N and increased with P application. Application of P showed an improvement in the oleic acid content of oil besides increasing total oil yield per ha^{-1} (Muralidharudu and Reddy, 1992).

Naphade and Naphade (1992) found that seed oil content increased from 28.89 per cent with no P to 32.22 per cent with 80 kg P_2O_5 ha^{-1}. Hiremath **et al**. (1992) reported that seed oil concentration increased with increasing P rate upto 100 kg P ha^{-1}.

2.1.5. Nutrient uptake

Phosphorus uptake was significantly increased as the level of N increased, but the level of P did not cause changes in the uptake of P (Varghese **et al**., 1976c). Pal (1979) reported that the peak period of P uptake was slow in the beginning but it was enhanced at flowering and attained maximum at the time of harvest. However the peak period of uptake was in between seedling and flowering period. Phosphorus content in plants increased upto knee high stage and thereafter decreased with plant age.

Rao **et al**. (1984) reported that P uptake increased with increasing level of P application. The content and uptake of P at different growth stages were significantly increased with every increase in the level of P (Hiremath **et al**., 1992). Loubser **et al**. (1990) reported that eleven per cent of applied P was recorded in vegetative plant parts. Uptake of N, P and B increased linearly upto 90 kg P_2O_5 ha^{-1} (Ateeque and Malewar, 1992). Ateeque **et al**. (1992) observed that the P concentration in DM as well as in seed was significantly increased with increasing levels of P with application upto 90 kg P_2O_5 ha^{-1}. The P concentration in DM

and seed increased from 0.27 to 0.36 and 0.92 to 1.02 per cent respectively with 90 kg P_2O_5 ha^{-1}.

A linear increase in the P uptake was observed with P application upto 80 kg P_2O_5 ha^{-1} (Naphade and Naphade, 1992) Ateeque **et al**. (1993) found that successive levels of P significantly increased the N, P and B content in sunflower DM and seed. Loubser and Human (1993) reported that high N levels increased the P content and concentration of all plant components in early growth stages only. High P levels increased the P content and concentration of all plant components sharply almost throughout.

Khokani **et al**. (1993) found NPK contents and uptake were unaffected by application of P_2O_5. Total P uptake increased upto 80 mg P_2O_5 ha^{-1} in low P soils and upto 60 mg P_2O_5 ha^{-1} in medium and high P soils (Balwinder Singh and Bishnoi, 1994).

2.2 Effect of foliar application of DAP.

Most of the applied phosphorus gets fixed in the soil and rendered unavailable to crops. Phosphorus availability in most soils is at a maximum in the pH range 5.5 to 6.5. At low pH values, the retention results largely from the reaction with Fe and Al and precipitation as $AlPO_4$ and $FePO_4$. Above pH 7.0, Ca^{2+} can precipitate with P as Ca-P minerals and P availability again decreases. Foliar application of nutrients using water soluble fertilizers is

one possible way to avoid such losses of phosphatic fertilizer. The foliar application of superphosphate and diammonium phosphate was found beneficial than soil application by several workers (Nalamwar **et al.**, 1972, Padole and Deshmukh, 1980).

Sagare **et al.** (1986) reported that highest seed yield of 1568 kg ha^{-1} was obtained in sunflower with foliar spray of urea 1.5 per cent plus diammonium phosphate (DAP) 0.5 per cent in combination with soil application of 30 kg P ha^{-1}. He also found that foliar spraying of 2.5 per cent DAP at button formation stage and flowering period increased the thousand seed weight. Foliar application of two per cent DAP after a prolonged dry spell increased the yield of sunflower by 19.9 per cent over control. (Narkhede and Patil, 1989).

Purushothaman **et al.** (1990) found that the combined application of 60 kg P_2O_5 ha^{-1} as basal with 20 kg P_2O_5 ha^{-1} as foliar spray in three splits on 30th, 40th and 50th day of sowing recorded the highest grain yield of 1740 and 1131 kg ha^{-1} in **Kharif and Rabi** respectively in soybean. Srinivasan and Ramasamy (1992) reported an increase in grain yield of 29 per cent in rainfed cowpea with the application of DAP 2 per cent at 20 and 30 days after sowing compared with absolute control. Krishna Reddy **et al.** (1992) suggested foliar spray of 2.5 per cent DAP in sunflower at button formation stage and flowering along with 30 kg N ha^{-1}

as basal dose for higher seed production under rainfed condition.

2.3. Significance of boron in crop production

Of the various micronutrient deficiencies, boron (B) deficiency in plants is most wide spread. Boron deficiency has been reported in over 70 countries world wide. Experimental results showed that B deficiency induced changes in plant growth and development, mineral element composition, enzyme activities, ultra-structure of cells, oxygen free radicals plasma membrane integrity and on mycorrhizal symbiosis (Marschner, 1990). Besides major fertilizer nutrients (NPK) the trace element boron appears to have special role in influencing seed filling.

2.3.1. Effect of boron on pollen development

Bobek and Kovachik (1972) reported that boron and calcium help in better pollen germination and result in higher seed set. Garg **et al.** (1979) found that germination capability, the size and the fertility of pollen grains of rice were considerably improved as a result of B application at 2.5 ppm concentration. They also reported that inclusion of B in the nutrient solution with optimum level induced some stimulatory effects on the pollen vitality and there by improved the grain yield of rice.

Lewis (1980) reported that for pollen tube growth, high B levels in stigma and style presumably are required for physiological inactivation of callose by formation of

borate callose complexes in the cells of the stigma and style at the interface with pollen tube wall.

B deficiency causes delay in tassel formation, decrease in pollen size, pollen germination and pollen production capacity of maize (Agarwal **et al.**, 1981).

2.3.2. Response of crops to boron fertilization

Application of boron either alone or in combination with FYM and sulphur helped in improving the quality of groundnut (Dongale and Zende, 1976; Survase **et al.**, 1986 and Patil **et al.**, 1987). Randhawa and Nayyar (1982) reported that application of boron was found to be beneficial in increasing the yield of wheat and paddy.

Shukla **et al.** (1983) found significant improvements in oil and protein content of mustard by application of boron alone or in combination with sulphur and zinc. The stover yield of mustard was found to be increased by the addition of boron under moisture stress condition (Dixit and Shukla, 1984).

2.3.3. Boron requirement of sunflower

A crop of sunflower yielding 3.5 t ha^{-1} required about 400 g ha^{-1} of B of which 20 per cent will be translocated to the seed (Andre Merrien, 1990). Gonzalez-Fernandez (1990) reported that the requirement of B was maximum during flowering and the plant was therefore most susceptible to limitations of B supply during this period.

The boron content of the 5th and 6th leaves under the flowering head should be between 30 and 40 ppm.

2.3.4. Effect of boron on sunflower

2.3.4.1. Yield, Yield attributes and quality characters

Studies conducted in India and elsewhere indicated that eventhough with no visible B deficiency symptoms, sunflower responded well to B fertilization as soil application or as foliar spray in terms of improved seed filling and yield (Blamey, 1976; Blamey and Chapman, 1982; Su, 1982). Satyanarayana **et al**. (1977) reported that application of B at two and four kg ha^{-1} increased the yield of sunflower by 38 and 59 per cent respectively over control.

Boron fertilization increased seed yield by an average of 48 per cent in cultivars 'Smena' and SO320'. There was relationship between seed yield and B concentration in the top most mature leaf at flowering in both the cultivars. The critical B concentrations in the top most mature leaf were determined as 32 and 35 ppm for Smena and SO320 respectively (Blamey **et al**., 1979).

Hanumantha Rao and Vidyasagar (1981a) reported that foliar application of B increased the plant height, stem girth, DM accumulation, total seed number per head, number and weight of filled seed per head, test weight and seed oil content. Seed yield of sunflower increased with the application of two to four kg ha^{-1} B but decreased at higher

rates of B application (>8 kg.ha^{-1}) (Comin **et al.**, 1987). Rerkasem **et al.** (1988) found that omitting B, depressed seed yield by 50 per cent in sunflower.

Sarkar and Sasmal (1989) found that applying 0.5 kg ha^{-1} B to sunflower grown in **Rabi** (winter) season increased the capitulum diameter, number of filled seeds head^{-1}, thousand seed weight and seed yield. Increase in seed yield of sunflower was reported with foliar spraying of Zn followed by B (Stoyanov **et al.**, 1990).

Tufail Ahmedkhan **et al.** (1990) found dusting of 2 kg ha^{-1} borax on sunflower heads during seed filling stage significantly increased the seed yield by 87 per cent, test weight by 60 per cent, seed filling by 25 per cent and head diameter by 21 per cent compared to control. They also found dusting borax on earheads gave the highest germination per cent of 96 and vigour index of 2162 compared to control (84 per cent germination and 1263 vigour index).

2.3.4.2. Nutrient uptake

Gomez **et al.** (1981) analysed sunflower leaves at flowering which were grown at deficient to toxic B levels. They noticed that there was a high significant inverse correlation between the B concentration in solution and the Mn content of leaves, whereas levels of Cu, Fe and Zn in leaves were unaffected.

Hanumantha Rao and Vidyasagar (1981b) reported that B when applied to soil resulted in increased N content

of leaf, K content of stems and K and P contents in petioles during early vegetative stage; N and P contents of leaves during flowering stage and P content of leaves and stems, and N and K contents of petioles at harvest. Boron when sprayed on foliage helped in the increase of the mineral composition of leaves, stems and petioles during different growth stages of sunflower.

They also noticed that foliar sprayed boron influenced the absorption and preferential translocation of mineral elements into different parts of the plant. Ateeque and Malewar (1992) reported that uptake of N, P and B by sunflower was highest when fertilized with boronated super phosphate as compared to SSP and DAP. The concentration of N, P and B in the seed of sunflower was significantly higher in boronated super phosphate applied crop (Ateeque **et al**., 1993).

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

With the objective of studying the effect of phosphorus and boron on the yield and seed setting of sunflower field experiments were conducted under irrigated conditions at Tamil Nadu Agricultural University, Coimbatore during **Rabi**, '94 and **Kharif**, '95. The details of the materials used and methods adopted during the course of investigations are presented hereunder.

3.1. Materials

3.1.1. Field location

The experiment was conducted in field No. 36 and 37, Eastern block of central farm, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore during 1994 and 1995. The farm is situated in the western zone of Tamil Nadu at 11°N latitude, 77°E longitude and at an altitude of 426.7 meters above mean sea level.

3.1.2. Weather and Climate

The normal weather conditions of the location (mean of 25 years) are as follows. A mean annual rainfall of 640 mm is received in 43 rainy days. The mean maximum and minimum temperatures are 31.5°c and 21.2°C respectively. Relative humidity ranged from 45 to 91 per cent during forenoon and afternoon. The mean bright sunshine hours per

day is 7.4 with a mean solar radiation of 400 cal. cm^{-2} day^{-1}. The weather parameters prevailed during the cropping period are presented in Table 1 and 2 and Fig. 1 and 2.

During **Rabi** season a total rainfall of 5.4 mm was received. The mean maximum and minimum temperature recorded were 35.9°C and 16.8°C. During **Kharif** season a total rainfall of 131.6 mm was received in 11 rainy days. The mean maximum and minimum temperatures recorded were 32.8°C and 21.1°C. In general, the weather during the study period was normal and favourable for crop growth.

.3.1.3. Soil characteristics

The texture of the experimental fields were sandy clay loam (Field No.36) and clay loam (Field No.37). Pre-sowing composite soil samples collected from surface to 15 cm depth of the field, analysed for physical properties and chemical characteristics and the data are given in the Table 3.

3.1.4. Crop and varieties

Sunflower hybrid MSFH-8 was chosen for the study in both the seasons. The MSFH-8 sunflower seeds were procured from private traders. The varietal characters are presented in Table 4.

3.1.5. Season

The experiments were conducted from December '94 to March '95 (**Rabi** crop) and June to October, '95 (**Kharif** crop).

Table 1. Weather data during the cropping period (Rabi, '94)

Std. week	Month & Date	Rain fall (mm)	Rainy days	Temperature (°C)		RH (%)		Sunshine hours	Wind Velocity (km/h)	Evaporation (mm)
				Max	Min	0722 h	1422 h			
	1994									
50	Dec 10-16	-	-	28.7	18.5	86	57	9.1	5.2	3.6
51	17-23	1.6	-	28.7	16.9	84	60	5.0	8.5	3.4
52	24-31	-	-	28.7	21.3	86	56	7.1	7.2	3.7
1	Jan 1-7	1.0	-	28.2	16.8	89	53	5.6	5.6	3.4
2	8-14	1.8	-	30.5	21.1	87	57	7.0	4.7	2.3
3	15-21	1.0	-	29.0	20.5	87	66	5.8	9.2	4.2
4	22-28	-	-	30.4	17.9	86	38	8.5	7.0	4.6
5	29-4	-	-	30.0	21.0	83	46	7.7	7.3	5.1
6	Feb 5-11	-	-	31.1	19.2	85	45	8.9	8.3	4.8
7	12-18	-	-	32.8	19.5	86	43	9.2	5.5	5.3
8	19-25	-	-	34.0	21.5	81	43	9.5	6.1	5.9
9	26-4	-	-	34.4	19.8	81	41	3.7	6.1	6.7
10	Mar 5-11	-	-	33.7	20.7	84	40	8.9	7.0	6.5
11	12-18	-	-	34.0	21.0	79	37	10.6	7.2	7.1
12	19-25	-	-	35.9	20.1	78	26	10.6	7.9	8.7

Source: The weather data were collected from the meteorological observatory of Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore -3.

Table 2. Weather data during the cropping period (Kharif, '95)

Std. week	Month & Date	Rain fall (mm)	Rainy days	Temperature (°C)		RH (%)		Sunshine hours	Wind Velocity (km/h)	Evaporation (mm)
				Max	Min	0722 h	1422 h			
	1995									
26	Jun 25-1	2.5	-	31.8	23.4	75	62	5.6	13.6	5.5
27	Jul 2-8	3.2	-	32.6	22.3	78	53	6.8	15.7	7.1
28	9-15	12.5	2	30.7	24.4	77	60	3.4	18.6	6.3
29	16-22	17.0	2	30.0	23.1	74	66	3.1	19.8	5.4
30	23-29	2.5	-	31.0	22.0	89	66	4.1	8.0	4.5
31	30-5	-	-	31.8	25.5	79	53	7.6	13.2	6.7
32	Aug 6-12	30.4	2	31.5	22.9	84	54	7.2	9.8	5.0
33	13-19	-	-	32.2	22.1	83	59	7.2	9.0	6.0
34	20-26	4.8	-	32.5	23.1	76	52	5.6	7.3	5.3
35	27-2	14.5	1	29.4	23.0	78	75	2.8	22.9	5.1
36	Sep 3-9	1.0	-	31.5	22.3	77	53	7.0	16.7	5.2
37	10-16	8.2	-	32.4	21.7	82	53	8.7	8.2	5.7
38	17-23	9.5	1	32.3	22.5	83	54	6.4	10.2	6.5
39	24-30	8.0	1	32.6	21.1	86	51	8.3	6.1	5.4
40	Oct 1-7	17.5	2	32.8	22.4	91	59	5.2	4.3	4.3

Source: The weather data were collected from the meteorological observatory of Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore -3.

Table 3. Soil characteristics

Particulars	Field No 37	Field No 36
a. Mechanical composition (Piper,1966)		
(1) Coarse sand (per cent)	20.23	28.53
(2) Fine sand (per cent)	21.54	23.24
(3) Silt (per cent)	24.68	15.67
(4) Clay (per cent)	30.73	28.93
(5) Texture	clay loam	sandy clay loam
b. Physical properties (Piper,1966)		
(1) Field capacity (per cent)	26.30	23.00
(2) Permanent wilting point (per cent)	12.50	12.00
(3) Bulk density ($g.cm^{-3}$)	1.32	1.24
c. Chemical properties.		
(1) Organic carbon (%) (Walkley and Black, 1934)	0.29	0.32
(2) Available nitrogen ($kg\ ha^{-1}$) (Subbaiah and Asija, 1956)	198(low)	161 (low)
(3) Available phosphorus ($kg\ ha^{-1}$) (Olsen **et al**., 1954)	18(medium)	16(medium)
(4) Available potassium ($kg\ ha^{-1}$) (Stanford and English, 1949)	535(high)	422(high)
(5) EC (dSm^{-1}) (1:2 soil: water solution) (Jackson, 1967)	0.84	0.40
(6) pH (1:2 soil:water solution) (Jackson, 1973)	7.90	7.60

Table 4. Characteristics of sunflower hybrid MSFH.8.

1.	Parentage	-
2.	Duration (days)	92-94
3.	Yield	
	(Rainfed) (kg ha^{-1})	1200
	(Irrigated (kg ha^{-1})	2100-2300
4.	Oil content (%)	42-44
5.	Ray floret	light yellow
6.	Height (cm)	190-200
7.	Seed size and colour	medium,black
8.	100 seed weight (g)	4-5
9.	Recommended spacing (cm)	60x30
10.	Head diameter (cm)	18-22

Fig. 1. Weather data during the cropping period (Rabi, '94)

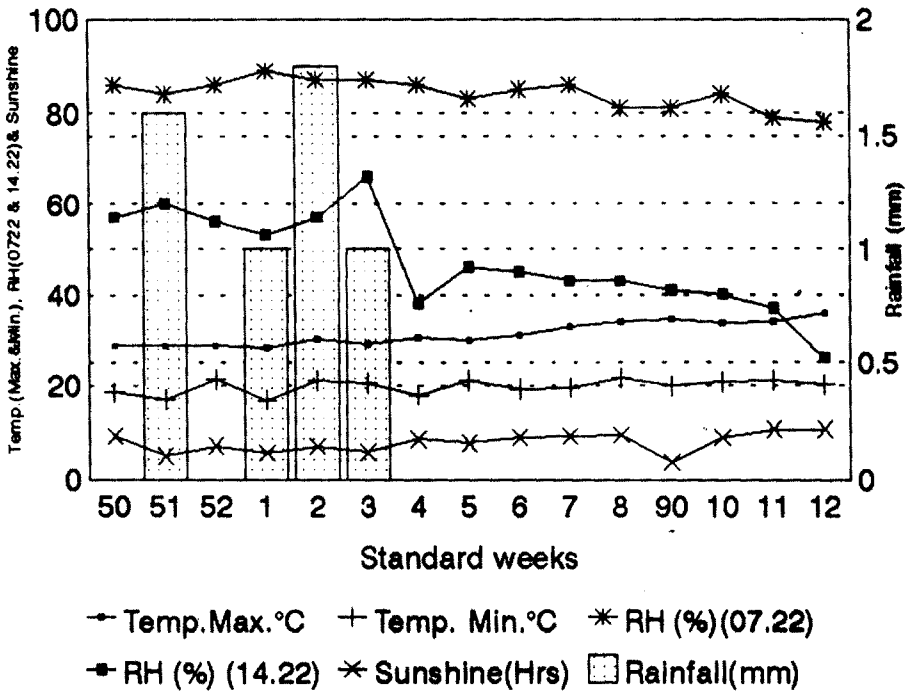
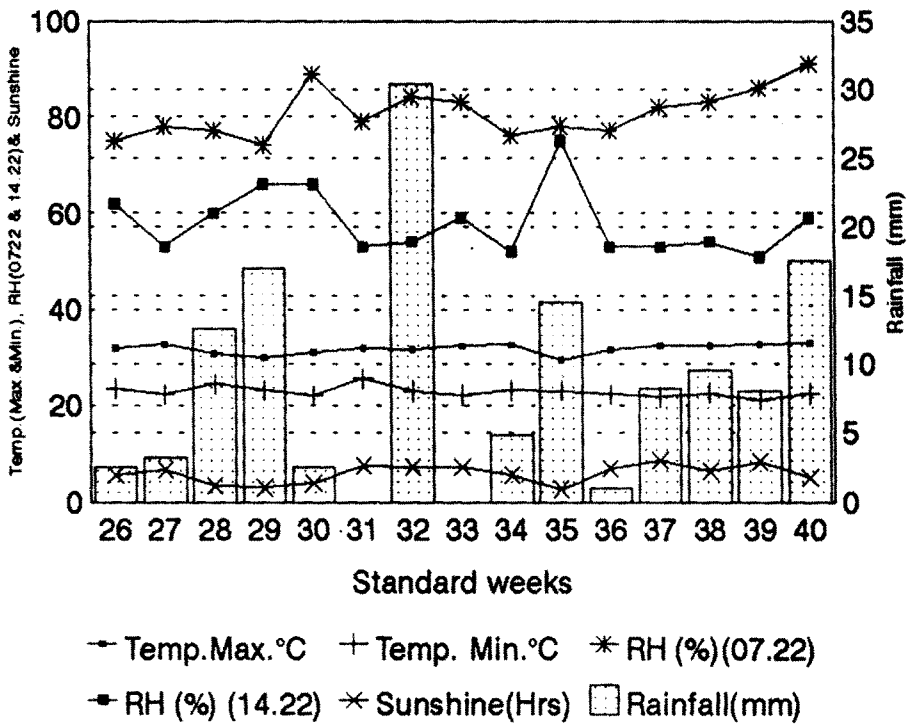


Fig. 2. Weather data during the cropping period (Kharif, '95)



3.1.6. Manures and fertilizers

The nutrient contents of fertilizers used are given hereunder:

1. Urea - 46% N
2. Single super phosphate - 16% P_2O_5
3. Diammonium phosphate - 18% N, 46% P_2O_5
4. Murate of potash - 60% K_2O
5. Borax - 11% B

3.2. Methods

3.2.1. Design and layout

The experiment was laid out in a Factorial Randomised Block Design (FRBD) with three replications. The layout plan of the experiment is shown in Fig. 3 and 4.

3.2.2. Treatment details

		Notation
T_1	- 0 kg P_2O_5 ha^{-1}	P_0S_0
T_2	- 30 kg P_2O_5 ha^{-1}	P_1S_0
T_3	- 60 kg P_2O_5 ha^{-1}	P_2S_0
T_4	- 90 kg P_2O_5 ha^{-1}	P_3S_0
T_5	- 0 kg P_2O_5 ha^{-1} + 2% DAP spray at flowering and one week after first spray	P_0S_1
T_6	- 30 kg P_2O_5 ha^{-1} + 2% DAP spray at flowering and one week after first spray	P_1S_1
T_7	- 60 kg P_2O_5 ha^{-1} + 2% DAP spray at flowering and	P_2S_1

one week after first spray.

T_8 - 90 kg P_2O_5 ha^{-1} + 2% DAP spray at flowering and one week after first spray — P_3S_1

T_9 - 0 kg P_2O_5 ha^{-1} + 0.2% Borax spray at flowering and one week after first spray — P_0S_2

T_{10} - 30 kg P_2O_5 ha^{-1} + 0.2% Borax spray at flowering and one week after first spray — P_1S_2

T_{11} - 60 kg P_2O_5 ha^{-1} + 0.2% Borax spray at flowering and one week after first spray — P_2S_2

T_{12} - 90 kg P_2O_5 ha^{-1} + 0.2% Borax spray at flowering and one week after first spray — P_3S_2

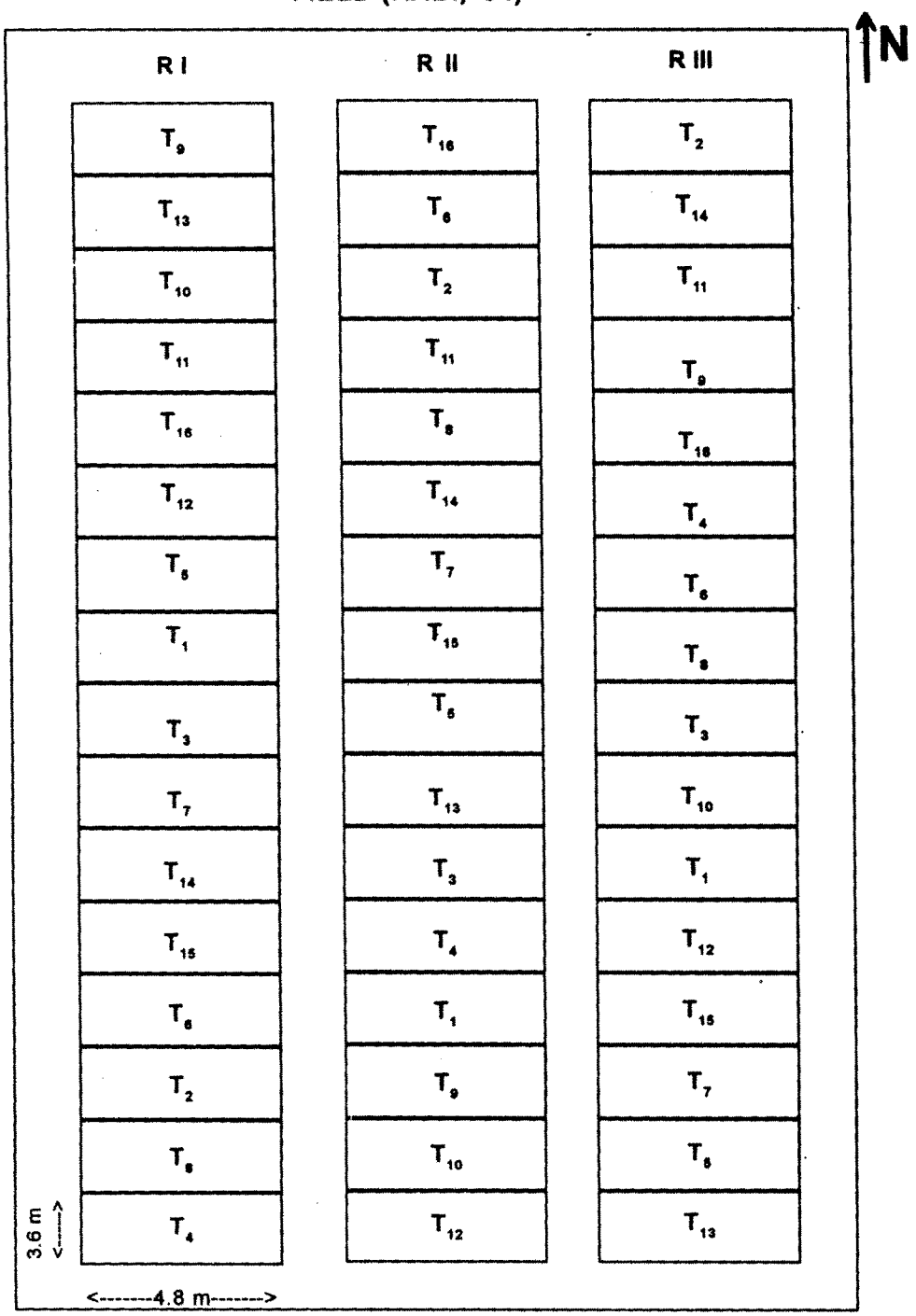
T_{13} - 0 kg P_2O_5 ha^{-1} + 2% DAP and 0.2% Borax spray at flowering and one week after first spray — P_0S_3

T_{14} - 30 kg P_2O_5 ha^{-1} + 2% DAP and 0.2% Borax spray at flowering and one week after first spray — P_1S_3

T_{15} - 60 kg P_2O_5 ha^{-1} + 2% DAP and 0.2% Borax spray at flowering and one week after first spray — P_2S_3

T_{16} - 90 kg P_2O_5 ha^{-1} + 2% DAP and 0.2% Borax spray at flowering and one week after first spray — P_3S_3

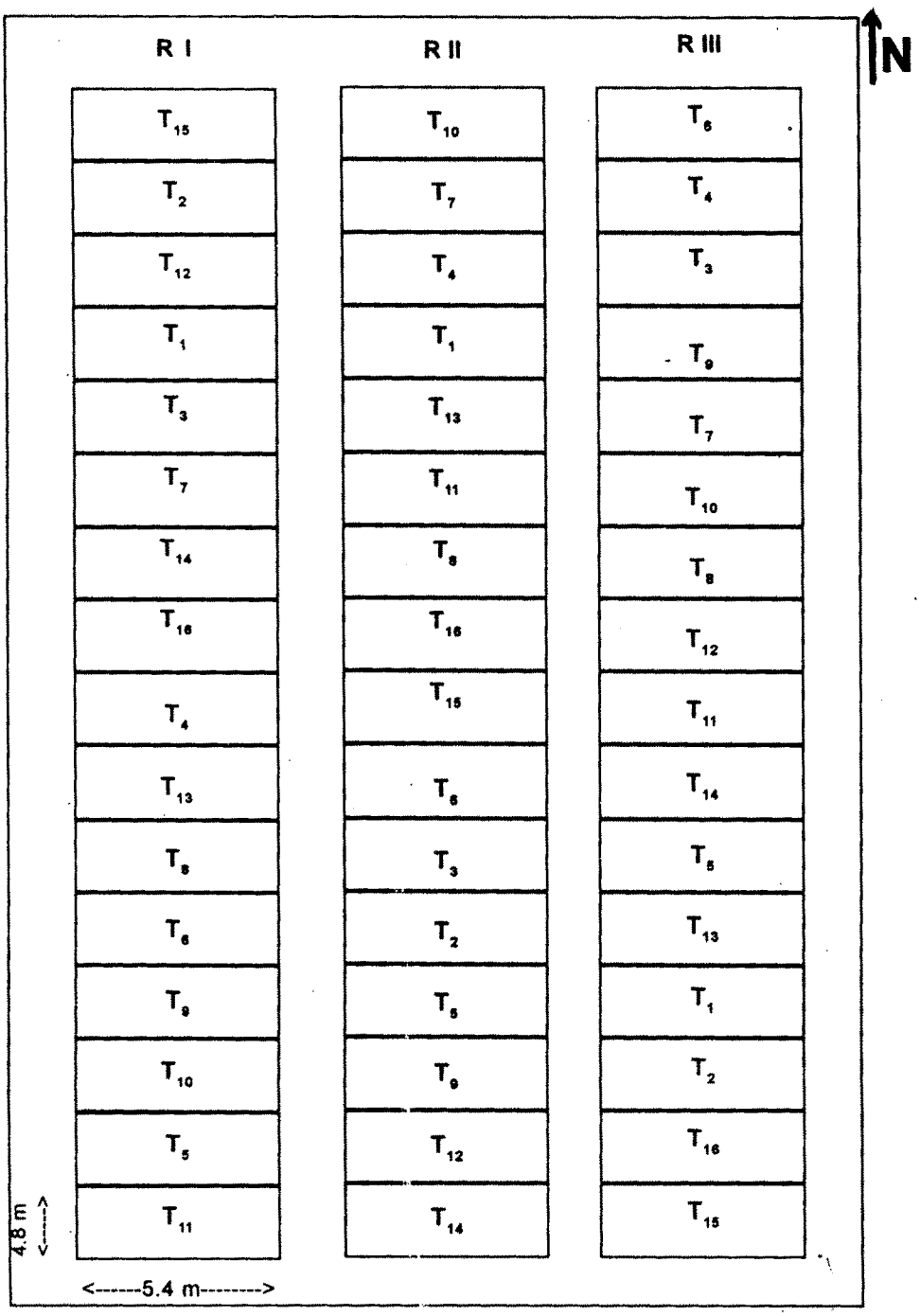
Fig. 3. FIELD LAYOUT PLAN OF THE EXPERIMENTAL FIELD (RABI, '94)



Design : FRBD
Date of sowing : 13.12.94

Gross Plot size: 4.8 x 3.6 m=17..28 m²
Net plot size : 3.6 x 3.0 m = 10.8 m²

Fig. 4. FIELD LAYOUT PLAN OF THE EXPERIMENTAL FIELD (KHARIF, '95)



Design : FRBD
Date of sowing: 26.06.95

Gross plot size : 5.4 x 4.8 m = 25.92 m²
Net plot size : 4.2 x 4.2. m = 17.64 m²

3.2.3. Plot size, sowing and harvest dates

The experimental details for the crop raised are given below.

Particulars	I crop (Rabi)	II crop (Kharif)
1. Plot size		
(a) Gross	4.8 m x 3.6 m	5.4 x 4.8 m
(b) Net	3.6 m x 3.0 m	4.2 x 4.2 m
2. Date of sowing	13.12.94	26.06.95
3. Date of harvest	22.03.95	05.10.95
4. Duration (days)	100	102

3.3. Crop management

3.3.1. Land preparation

The experimental fields were ploughed thoroughly with mould board plough, harrowed and then beds were formed.

3.3.2. Seeds

3.3.2.1. Seed treatment

Seeds were treated with carbendazim at the rate of 2 g kg^{-1} of seeds to protect the crop against seed-borne diseases.

3.3.2.2. Sowing

The seeds were dibbled in the beds at a spacing of 60x30 cm at the rate of two seeds per hill and later thinned to single plant to maintain the population.

3.3.3. Fertilizer application

A common dose of nitrogen as urea to supply 60 kg N ha^{-1} and potassium as murate of potash to supply 60 kg K

ha^{-1} were supplied. As per the treatment schedule, phosphatic fertilizer was applied in different doses as super phosphate. Full dose of phosphorus and potassium were applied basally at the time of sowing. Nitrogen was applied in two splits i.e., 50 per cent as basal dose and another 50 per cent 30 DAS. The quantities of fertilizers were calculated based on its nutrient contents of different fertilizers.

As per the treatment schedule, foliar spraying of 2% diammonium phosphate (DAP) and 0.2% borax were sprayed twice. For the treatment T_{13} to T_{16}, 2% DAP and 0.2% borax solutions were prepared separately and they were mixed and sprayed. First spray was given at the time of flowering and second spray was given one week after the first spray.

Diammonium phosphate 2% solution was obtained by dissolving 20 g DAP in one litre water. This solution was kept over night. The supernatent solution was decanted in the next morning and used for spraying. Quantity of DAP used for spraying was six kgs ha^{-1} per spraying.

Borax 0.2% solution was obtained by dissolving two grams borax in one litre water. Freshly prepared borax solution was used for spraying. Quantity of borax used for spraying was 600 g ha^{-1} per spraying

3.3.4. Irrigation

Three irrigations were given during early vegetative stage including life irrigation. Subsequent

irrigations at bud formation, flowering and grain filling stages were given.

3.3.5. Gap filling and thinning

Gap filling was done at six days after sowing. Thinning was done 15 day after sowing to maintain one healthy plant per hill.

3.3.6. After cultivation

Fluchloralin as pre-emergence herbicide was sprayed @ 2 lit ha^{-1} on third day of sowing. Hand hoeing and weeding was given at 30 DAS for effective weed management.

3.3.7. Crop protection

As per the recommendations prophylactic measures were taken and the crops were kept free of pest and diseases incidence.

3.3.8. Harvesting and threshing

The border rows in each plot were harvested first and the rows in net plot were harvested separately. The heads (capitulum) were harvested after maturity. Then the stalks were cut close to the ground.

Threshing was done manually and the seeds were separated. The cleaned seeds were dried and the plot yield was recorded at 12 per cent moisture.

3.4. Biometric observations

For recording biometric observations, five representative plants in each plot were selected at random

and tagged. Relevant observations were recorded at stipulated time in all the replications. Observations on biometric characters taken upto 60 DAS were given only for phosphorus treatments (P_{0}, $_{30}$, P_{60} and P_{90}).

3.4.1. Growth attributes

3.4.1.1. Plant height

The plant height was measured from the ground level to the tip of the plant at 30, 60 and 90 DAS and expressed in cm.

3.4.1.2. Stem girth

The girth of the stem at the lowest node was recorded at 30, 60 and 90 DAS and expressed in cm.

3.4.1.3. Leaf area index (LAI)

The length and breadth of the leaves were measured at 30, 60 and 90 DAS. The leaf area was calculated using the factor 0.65 as given by Lazarov (1965). Leaf area index was calculated by dividing the leaf area by area of the land occupied by the plant.

3.4.1.4. Days to fifty per cent flowering

The number of days to fifty per cent flowering of the population was recorded.

3.4.1.5. Dry matter production

The dry weight of five plants from each plot was recorded at 30, 60 and 90 DAS and expressed in $kg.ha^{-1}$

3.4.2. Yield attributes

3.4.2.1. Head (Capitulum) diameter

The diameter of the flower head was measured at maturity and expressed in cm.

3.4.2.2. Total number of seeds per capitulum

The total number of seeds in the representative samples were counted and the mean value per plant was recorded.

3.4.2.3. Percentage of filled seeds

The ratio of filled seeds to the total number of seeds per capitulum was calculated and expressed in percentage.

$$\text{Percentage of filled seeds} = \frac{\text{Number of filled seeds}}{\text{Total number of seeds per capitulum}} \times 100$$

3.4.2.4. Test weight

The weight of hundred filled seeds (randomly sampled) was recorded and expressed in grams.

3.4.3. Yield

3.4.3.1. Seed yield

The seed yield was recorded for the net plot and then converted into per hectare basis and expressed in kg ha^{-1}.

3.4.3.2. Stalk yield

Plot wise stalk yield was calculated and converted into per hectare basis and expressed in kg ha^{-1}.

3.5. Quality parameter

3.5.1. Oil content

Oil content of sunflower seed was estimated with the nuclear magnetic resonance (NMR) instrument and expressed in per cent.

3.6. Chemical analysis

Plants collected for recording the DMP were chopped into small pieces and powdered in a Willey mill. The powdered material was used for chemical analysis.

3.6.1. Nitrogen uptake

The total N content in plant was determined by microkjeldahl method as suggested by Humphries (1956). The uptake of N was worked out by multiplying N content of plant tissue with DMP at 30, 60 and 90 DAS and expressed in kg ha^{-1}.

3.6.2. Phosphorus uptake

Phosphorus content in plant was determined by using photoelectric colorimeter (Jackson,1967). The uptake of P was worked out by multiplying its content with dry matter production at 30, 60 and 90 DAS and expressed in kg ha^{-1}.

3.6.3. Potassium uptake

Potassium content in plant was estimated in di-acid extract using flame photometer (Jackson, 1967). Potassium uptake was worked out by multiplying its content with DMP at 30, 60, and 90 DAS and expressed in kg ha^{-1}.

3.7. Soil analysis

Composite soil samples were collected before sowing of sunflower. Further soil samples were taken at post harvest stage. Soil samples collected at 0-15 cm depth were dried and powdered and passed through 2 mm sieve and analysed for the following constituents.

The initial soil sample was analysed for mechanical and chemical properties such as mechanical composition, organic carbon, available N, available P_2O_5, available K_2O, pH and EC. Soil samples collected at post harvest stages were analysed for available N, P_2O_5 and K_2O.

3.7.1. Mechanical composition

Mechanical composition was worked out by following the international pipette method as detailed by Piper (1966).

3.7.2. pH and EC

Soil pH was estimated through glass electrode by pH meter (Trombag model) and EC through conductivity bridge (Solu-bridge) using a soil water suspension of 1:2 ratio.

3.7.3. Organic carbon

Organic carbon was estimated by the wet digestion method suggested by Walkley and Black (1934).

3.7.4. Available N

This was estimated by alkaline $KMnO_4$ method suggested by Subbaiah and Asija (1956) and expressed in kg ha^{-1}.

3.7.5. Available P

This was estimated by the method suggested by Olsen **et al**. (1954) and expressed in kg ha^{-1}.

3.7.6. Available K

This was estimated by the neutral normal ammonium acetate extraction method and flame photometry as described by Stanford and English (1949) and expressed in kg ha^{-1}.

3.8. Economics

3.8.1. Cost of cultivation

The expenditure incurred from field preparation and sowing to harvest was worked out.

3.8.2. Gross returns

Total income obtained from the grain was worked out, considering the current market prices for inputs and outputs.

3.8.3. Net returns

Net return was obtained by subtracting the cost of cultivation from the gross return.

3.8.4. Benefit : cost ratio (BCR)

This was worked out by using the formula.

$$B.C.R. = \frac{\text{Gross returns}}{\text{Cost of cultivation}}$$

3.9. Statistical analysis

The data on the various parameters studied during the course of investigation were subjected to statistical analysis following the procedure given by Sukhatme and Amble (1985) for a factorial randomised block design (FRBD). Wherever the treatment differences were found significant by the 'F' test, critical differences were worked out at five per cent probability level and the values were furnished. Treatment differences that were non-significant, were denoted as 'NS'.

EXPERIMENTAL RESULTS

CHAPTER IV

EXPERIMENTAL RESULTS

The results of the field experiments conducted at Tamil Nadu Agricultural University Farm, Coimbatore during **Rabi**, '94 and **Kharif**, '95 to study the effect of phosphorus and boron on the yield and seed setting of sunflower hybrid (MSFH-8) under irrigated conditions are presented below.

4.1. GROWTH ATTRIBUTES

Observations recorded on plant height, stem girth, DMP and LAI are presented below.

4.1.1. Plant height (Table 5, 6 and 7)

Plant height is an indicator of growth performance of the crop as influenced by environment and management factors. During **Rabi**, '94, application of 90 kg P_2O_5 ha^{-1} recorded the maximum plant height at 60 and 90 DAS. At 30 DAS, phosphorus application did not increase the plant height significantly. During **Kharif**, '95, application of phosphorus increased the plant height significantly at all stages.

In both the crops foliar application of di-ammonium phosphate at 2 per cent and borax at 0.2 per cent either alone or in combination did not significantly influence the plant height at 90 DAS.

Table 6. Plant height, stem girth and leaf area index (LAI) - **Kharif**, '95

Treatment	Plant height (cm)		Stem girth (cm)		LAI	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
P_0	23.03	124.1	2.42	5.90	0.46	1.81
P_1	22.53	136.2	2.45	5.92	0.54	1.94
P_2	23.34	143.9	2.46	5.93	0.63	2.00
P_3	24.94	146.6	2.51	6.10	0.64	2.11
SEd	1.41	3.52	0.10	0.26	0.01	0.03
CD(P=0.05)	2.88	7.19	NS	NS	0.02	0.06

Interaction effect between phosphorus levels and foliar spraying of DAP and borax was not significant in both the seasons.

4.1.2. Stem girth (Table 5, 6 and 7)

Phosphorus application influenced the girth of the stem. The girth was higher during **Rabi** than **Kharif** season. In the crop grown during **Rabi**, '94, the girth of the stem was significantly influenced by the application of phosphorus at 60 DAS but at 30 and 90 DAS the stem girth was not significantly influenced by P application. Application of 90 kg P_2O_5 ha^{-1} recorded higher stem girth followed by 60 kg P_2O_5 ha^{-1}. During **Kharif**, '95, application of 90 kg P_2O_5 ha^{-1} and 60 kg P_2O_5 ha^{-1} recorded higher stem girth. But the effect was not significant at 30 and 60 DAS.

The stem girth was not markedly influenced by foliar application of 2 per cent DAP and 0.2 per cent borax either alone or in combination in both the seasons.

Interaction effect between the levels of phosphorus (0, 30, 60 and 90 kg P_2O_5 ha^{-1}), foliar spraying of DAP (2 per cent) and borax (0.2 per cent) was also not significant during **Rabi** and **Kharif** seasons.

4.1.3. Leaf area index (LAI) (Table 5 and 6)

Leaf area index determines the total photosynthesizing area available to the plant and the

Table 6. Plant height, stem girth and leaf area index (LAI) - **Kharif**, '95

Treatment	Plant height (cm)		Stem girth (cm)		LAI	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
P_0	23.03	124.1	2.42	5.90	0.46	1.81
P_1	22.53	136.2	2.45	5.92	0.54	1.94
P_2	23.34	143.9	2.46	5.93	0.63	2.00
P_3	24.94	146.6	2.51	6.10	0.64	2.11
SEd	1.41	3.52	0.10	0.26	0.01	0.03
CD(P=0.05)	2.88	7.19	NS	NS	0.02	0.06

Table 7. Plant height and stem girth (90 DAS)

Treatment	Rabi, '94		Kharif, '95	
	Plant height (cm)	Stem girth (cm)	Plant height (cm)	Stem girth (cm)
P_0	144.4	5.69	138.4	4.13
P_1	153.2	5.81	146.3	4.18
P_2	160.9	6.0	156.9	4.61
P_3	163.8	6.1	158.7	4.69
SEd	3.96	0.25	2.99	0.19
CD(P=0.05)	8.08	NS	6.11	0.39
S_0	154.0	5.93	149.1	4.33
S_1	157.3	6.02	150.0	4.38
S_2	155.8	5.92	150.2	4.53
S_3	155.1	5.71	151.1	4.37
SEd	3.96	0.25	2.99	0.19
CD(P=0.05)	NS	NS	NS	NS
P x S				
SEd	7.92	0.49	5.98	0.37
CD(P=0.05)	NS	NS	NS	NS

quantum of source that would be ultimately available for translocation to the sink.

Phosphorus application had significant effect on LAI. During **Rabi** season, application of 90 kg P_2O_5 ha^{-1} and 60 kg P_2O_5 ha^{-1} recorded higher LAI at 30 and 60 DAS. Similar trend was observed during **Kharif** season also.

4.1.4. Dry matter production (Table 8 and 9)

Dry matter production of a crop reflects its efficiency of utilization of available resources such as solar energy, moisture and nutrients under the existing environmental conditions.

Application of phosphorus influenced the dry matter production significantly at all stages. Higher dry matter production was recorded with 90 kg P_2O_5 ha^{-1} and was on par with that at 60 kg P_2O_5 ha^{-1}. Application of 30 kg P_2O_5 ha^{-1} recorded lesser DMP than 90 and 60 kg P_2O_5 ha^{-1} but it was higher than control. Similar trend was observed at 30, 60 and 90 DAS during both **Rabi** and **Kharif** seasons.

There was no significant effect on dry matter production due to foliar spraying of 2 per cent DAP and 0.2 per cent borax at 90 DAS in both the seasons.

In both the seasons, interaction between P levels and foliar application of DAP at 2 per cent and borax at 0.2 per cent was not significant.

Table 8. Dry matter production (kg/ha)

Treatment	Rabi, '94		Kharif, '95	
	30 DAS	60 DAS	30 DAS	60 DAS
P_0	460.0	2834	413.1	2730
P_1	528.8	3041	477.1	2886
P_2	611.8	3334	557.4	3269
P_3	623.5	3347	565.0	3283
SEd	15.41	61.5	14.49	90.55
CD(P=0.05)	31.47	125.6	29.59	184.90

Table 9. Dry matter production (kg/ha) - 90 DAS

	Rabi, '94	Kharif, '95
P_0	5435	5253
P_1	5834	5498
P_2	6232	5839
P_3	6319	5856
SEd	130.4	152.3
CD(P=0.05)	266.3	311.0
S_0	5975	5542
S_1	5954	5632
S_2	5903	5620
S_3	5988	5653
SEd	130.4	152.3
CD(P=0.05)	NS	NS
P x S		
SEd	260.8	304.7
CD(P=0.05)	NS	NS

4.1.5. Days to fifty per cent flowering (Table 10)

Number of days taken for 50 per cent flowering was not influenced by the application of different levels of phosphorus during **Rabi** and **Kharif** seasons.

4.2. YIELD ATTRIBUTES

Yield components like diameter of capitulum, number of seeds per head, percentage of filled seeds and test weight were recorded and presented below.

4.2.1.Head (Capitulum) diameter (Table 11 and 12; Fig. 5 and 6)

The head diameter is one of the criteria which contributes to the yield of sunflower. **Rabi** season crop recorded higher head diameter than the **Kharif** crop.

The diameter of the head was favourably influenced by phosphorus application. During **Rabi** season, the highest head diameter (14.39 cm) was observed with the application of 90 kg P_2O_5 ha^{-1} whereas in **Kharif** season the highest diameter of 13.69 cm was observed with the application of 60 kg P_2O_5 ha^{-1}. During both the seasons, higher levels of P (90 and 60 kg P_2O_5 ha^{-1}) were superior to 30 kg P_2O_5 ha^{-1} and control.

Foliar spraying of 2 per cent DAP and 0.2 per cent borax alone as well as in combination had no significant effect on the diameter of head in both the seasons.

Table 10. Days to 50% flowering.

Treatments	**Rabi**, '94	**Kharif**, '95
P_0	65.0	64.1
P_1	65.0	63.8
P_2	64.5	63.8
P_3	64.6	63.6
SEd	0.37	0.75
CD(P=0.05)	NS	NS

Table 11. Yield components of sunflower - **Rabi**, '94

Treatments	Head diameter (cm)	No of seeds /capitulum	Percentage of filled seeds	Test weight (g)
P_0	12.05	737	82.3	3.70
P_1	12.75	800	85.0	3.95
P_2	14.29	869	87.7	4.22
P_3	14.39	876	89.2	4.26
SEd	0.38	25.64	1.06	0.062
CD(P=0.05)	0.78	52.36	2.17	0.126
S_0	13.33	775.	79.9	4.00
S_1	13.45	826	83.4	4.05
S_2	13.42	833	88.9	4.03
S_3	13.28	848	91.9	4.04
SEd	0.38	25.64	1.06	0.062
CD(P=0.05)	NS	52.36	2.17	NS
P x S				
SEd	0.76	51.29	2.13	0.125
CD(P=0.05)	NS	NS	NS	NS

Table 12. Yield components of sunflower - **Kharif**, '95.

Treatments	Head diameter (cm)	No of seeds / capitulum	Percentage of filled seeds	Test weight (g)
P_0	12.66	605	82.5	3.65
P_1	12.68	662	86.3	3.83
P_2	13.69	717	89.5	4.07
P_3	13.60	735	91.8	4.17
SEd	0.36	18.69	0.77	0.069
CD(P=0.05)	0.74	38.16	1.58	0.143
S_0	13.37	658	84.5	3.90
S_1	13.38	673	87.0	3.94
S_2	12.97	684	88.3	3.96
S_3	12.97	704	90.3	3.92
SEd	0.36	18.69	0.77	0.069
CD(P=0.05)	NS	38.16	1.58	NS
P x S				
SEd	0.73	37.38	1.55	0.139
CD(P=0.05)	NS	NS	NS	NS

Fig. 5. Diameter of the head

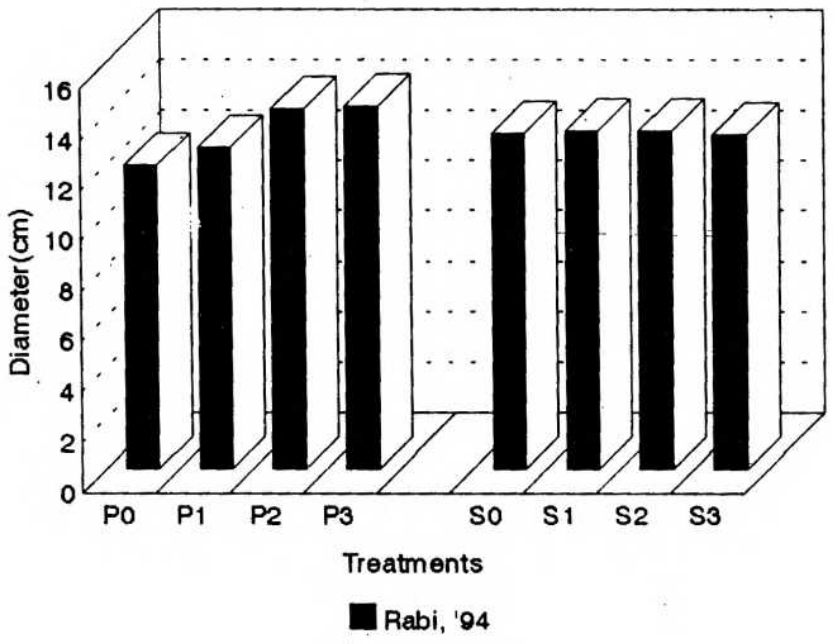
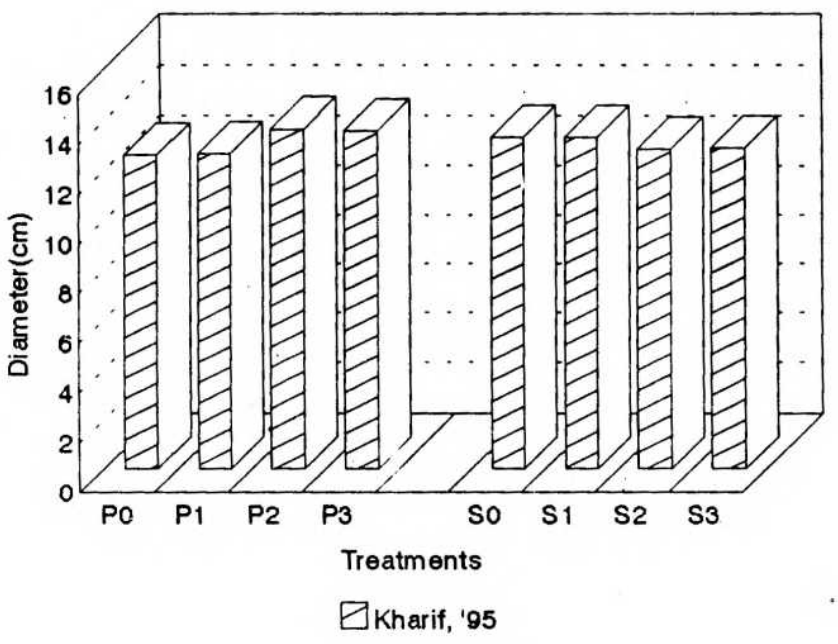


Fig. 6. Diameter of the head



In both the seasons, there was no interaction effect between the levels of P, 2 per cent DAP and 0.2 per cent borax foliar spraying.

4.2.2.Number of seeds per head (Table 11 and 12; Fig. 7 and 8)

Higher number of seeds per head was produced during **Rabi** season than **Kharif** season. Phosphorus application had significant effect on the number of seeds per head. During **Rabi** season, among the various levels of phosphorus tried, 90 kg P_2O_5 ha^{-1} recorded significantly higher number of seeds per head and on par with 60 kg P_2O_5 ha^{-1}. Number of seeds produced at 30 kg P_2O_5 ha^{-1} was higher than control. In **Kharif** season also higher number of seeds was recorded at 90 kg P_2O_5 ha^{-1} followed by 60 kg P_2O_5 ha^{-1}.

In both **Rabi** and **Kharif** seasons, spraying DAP at 2 per cent and borax at 0.2 per cent alone and in combination also increased the number of seeds per head. Among the different foliar spraying treatments, 2 per cent DAP and 0.2 per cent borax when sprayed in combination (S_3) resulted in higher number of seeds per head. Spraying 2 per cent DAP and 0.2 per cent borax alone also increased the number of seeds and were superior to control (no foliar spray).

Interaction effect between P levels and foliar application was not significant in both the seasons.

Fig. 7. Number of seeds per capitulum

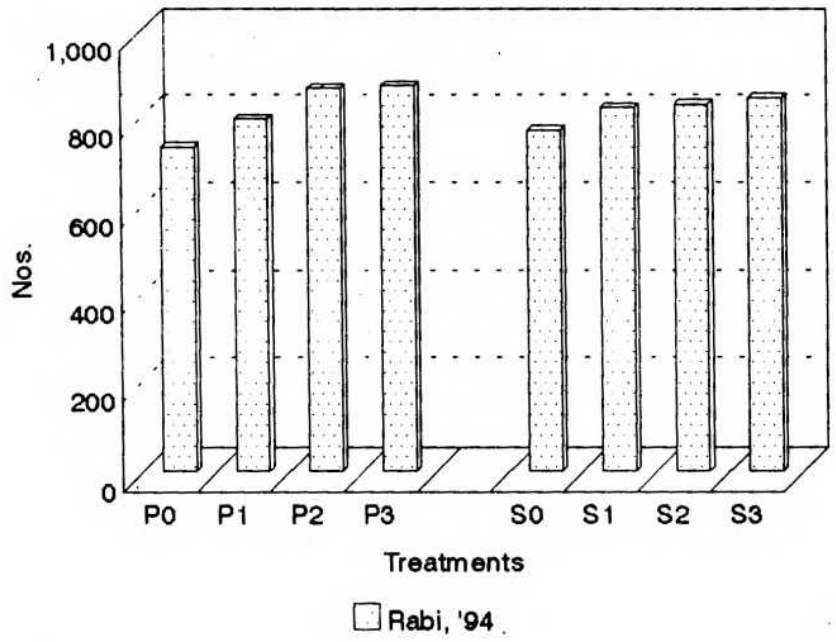
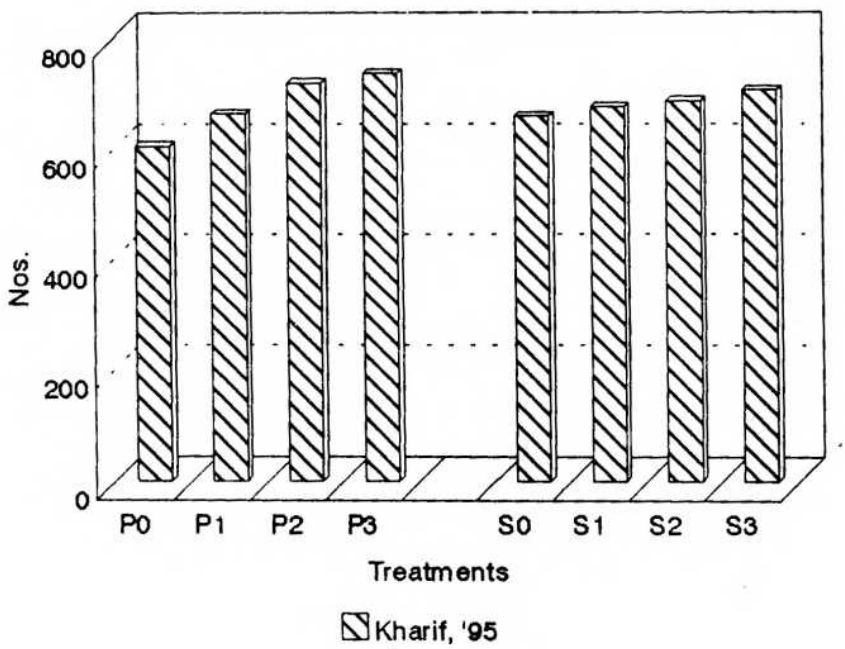


Fig. 8. Number of seeds per capitulum



4.2.3.Percentage of filled seeds (Table 11 and 12; Fig. 9 and 10)

Percentage of filled seeds increased significantly with an increase in the levels of phosphorus. During **Rabi**, higher percentages of filled seeds (89.2 per cent and 87.7 per cent) were obtained with the application of 90 and 60 kg P_2O_5 ha^{-1} respectively. Similarly in **Kharif** season also application of 90 and 60 kg P_2O_5 ha^{-1} recorded 91.8 and 89.5 per cent of filled seeds respectively and were superior to the application of 30 kg P_2O_5 ha^{-1} and no P (control). Percentages of filled seeds recorded in control were 82.2 and 82.5 during **Rabi** and **Kharif** seasons respectively.

An increased percentage of filled seeds was recorded with foliar spraying of 2 per cent DAP and 0.2 per cent borax alone as well as in combination. DAP and borax when sprayed in combination (S_3) resulted in better seed filling percentage than separate spraying of DAP, borax and no spray. Combined spray of 2 per cent DAP and 0.2 per cent borax recorded 91.9 and 90.3 per cent of filled seeds during **Rabi** and **Kharif** seasons respectively.

In both the seasons, interaction between P levels and foliar spraying was not significant.

4.2.4. Test weight (Table 11 and 12; Fig. 11 and 12)

Phosphorus levels had increased the test weight significantly. During **Rabi** season, among the different levels of phosphorus tried, 90 kg P_2O_5 ha^{-1} recorded the

Fig. 9. Percentage of filled seeds

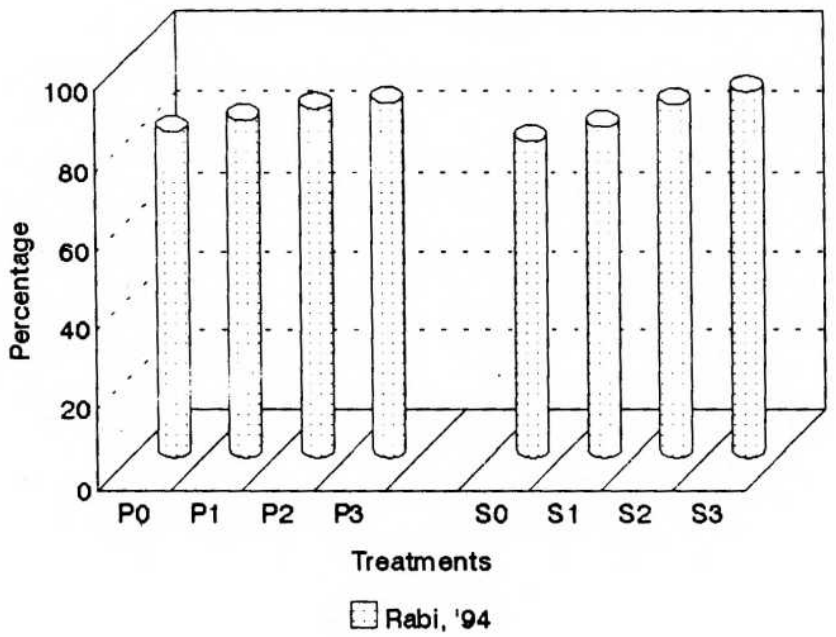


Fig.10. Percentage of filled seeds

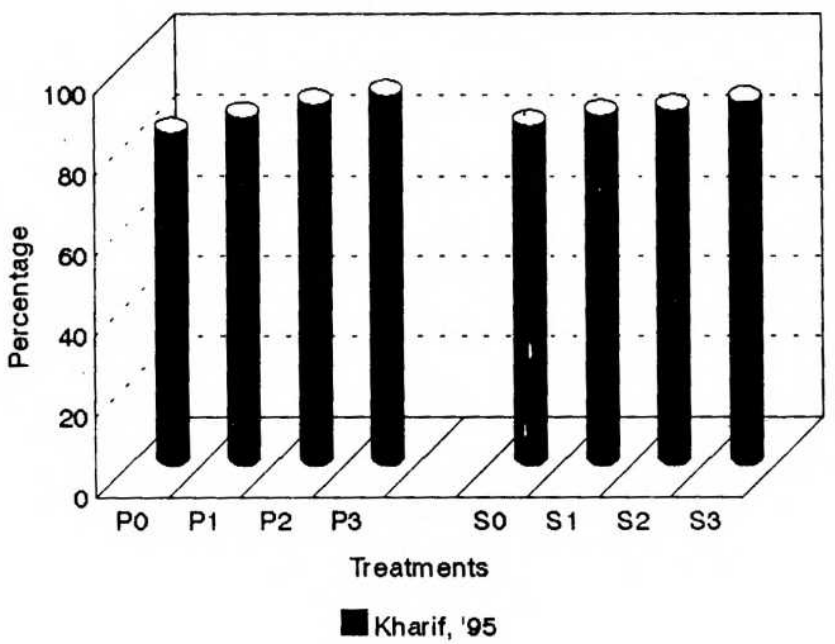


Fig.11. Hundred seed weight (g)

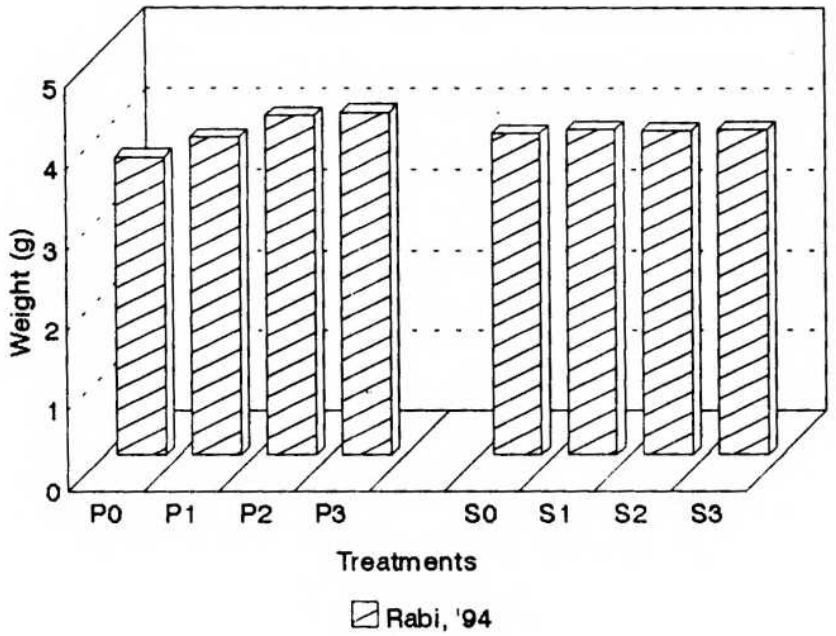
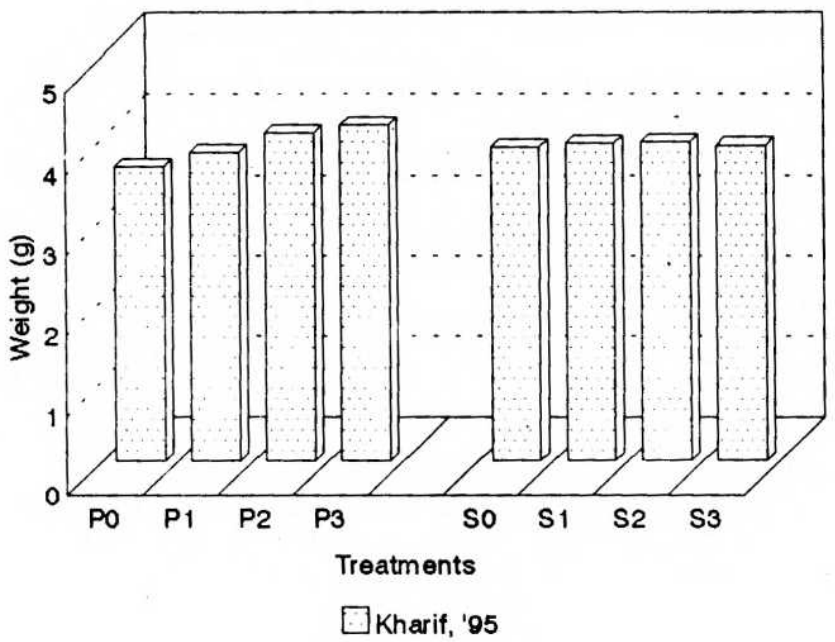


Fig.12. Hundred seed weight (g)



highest test weight (4.26 g) which was on a par with 60 kg P_2O_5 ha^{-1} and these two levels were superior to 30 kg P_2O_5 ha^{-1} and control. Similar trend of increased test weight with an increase in level of P was recorded during **Kharif** season also.

The test weight was not significantly influenced by foliar application of 2 per cent DAP and 0.2 per cent borax during both the seasons.

There was no interaction between P levels and foliar spraying of DAP and borax.

4.3. YIELD

4.3.1. Seed yield (Table 13 and 14; Fig. 13 and 14)

Higher seed yield was recorded during **Rabi** season than **Kharif** season. Phosphorus application significantly increased the seed yield. During **Rabi** season, the highest seed yield of 1445 kg ha^{-1} was obtained with the application of 90 kg P_2O_5 ha^{-1}. Application of 60 kg P_2O_5 ha^{-1} recorded 1413 kg ha^{-1} of seed yield. The yield recorded by 90 kg P_2O_5 ha^{-1} and 60 kg P_2O_5 ha^{-1} were at par with each other. In **Kharif** season the seed yield was 1284 kg ha^{-1} and 1262 kg ha^{-1} for application of 90 kg P_2O_5 ha^{-1} and 60 kg P_2O_5 ha^{-1} respectively. Seed yields obtained with no P application were 1123 kg ha^{-1} and 986 kg ha^{-1} during **Rabi** and **Kharif** seasons respectively.

Seed yield was increased significantly with different foliar spraying treatments. During both **Rabi** and

Table 13. Yield and oil content of sunflower-**Rabi**, '94

Treatments	Seed yield (kg /ha)	Stalk yield (kg/ha)	Oil content (percentage)	Oil yield (kg/ha)
P_0	1123	2516	34.00	382.2
P_1	1322	2693	34.45	455.7
P_2	1413	2987	35.82	506.2
P_3	1445	3031	35.87	518.8
SEd	40.59	130.9	0.41	15.2
CD(P=0.05)	82.88	267.3	0.84	31.04
S_0	1224	2802	34.55	423.4
S_1	1319	2781	35.17	465.4
S_2	1336	2849	35.28	473.0
S_3	1424	2795	35.14	501.2
SEd	40.59	130.9	0.41	15.2
CD(P=0.05)	82.88	NS	NS 3	1.04
P x S				
SEd	81.19	261.9	0.83	30.41
CD(P=0.05)	NS	NS	NS	NS

Table 14. Yield and Oil content of sunflower-**Kharif**, '95.

Treatments	Seed Yield (kg/ha)	Stalk yield (kg/ha)	Oil content (percentage)	Oil yield (kg/ha)
P_0	986	2285	35.53	350.1
P_1	1151	2415	36.47	419.6
P_2	1262	2743	37.23	470.0
P_3	1284	2770	37.71	484.1
SEd	35.46	78.15	0.56	13.09
CD(P=0.05)	72.41	159.58	1.14	26.73
S_0	1086	2567	36.78	400.4
S_1	1164	2551	36.52	426.0
S_2	1175	2496	36.82	433.5
S_3	1258	2597	36.82	463.8
SEd	35.46	79.15	0.56	13.09
CD(P=0.05)	72.41	NS	NS	26.73
P x S				
SEd	70.91	156.3	1.13	26.19
CD(P=0.05)	NS	NS	NS	NS

Fig.13. Seed yield (kg/ha)

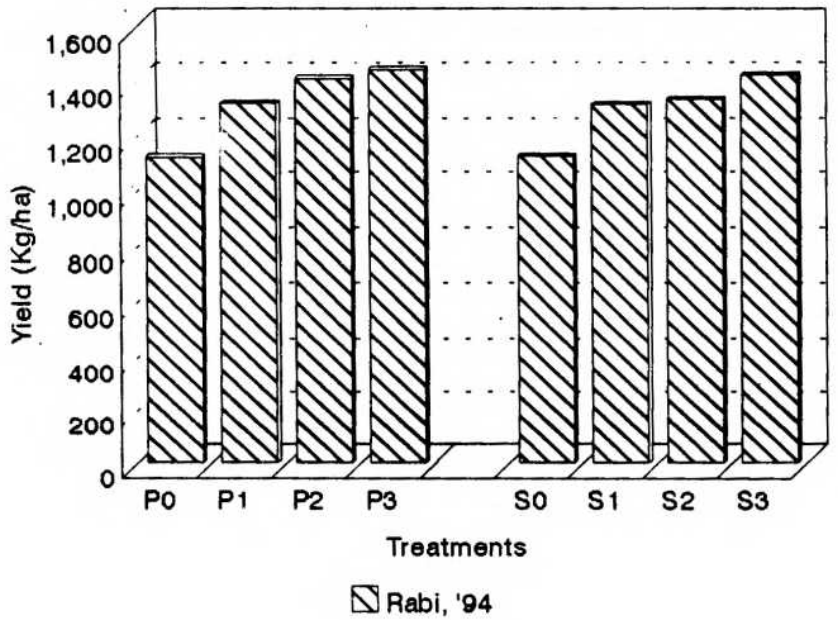
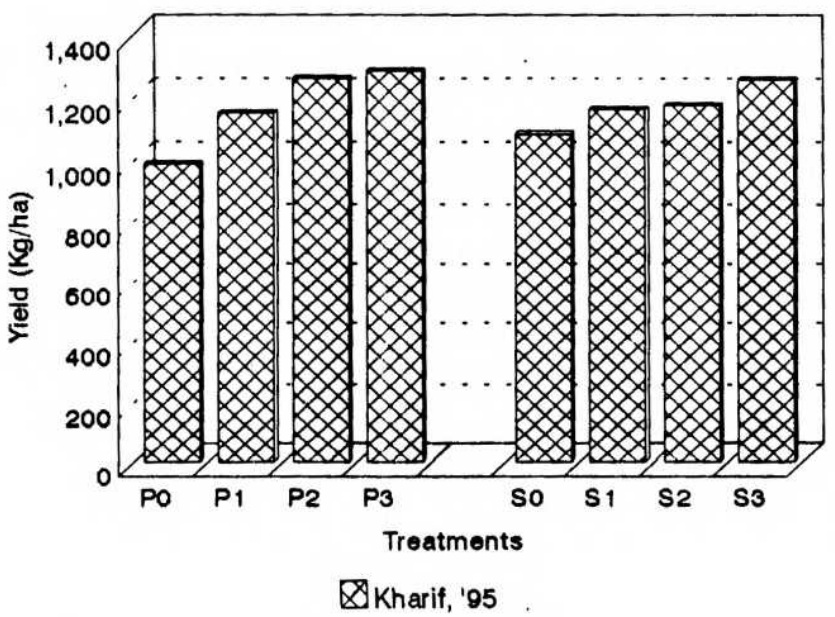


Fig.14. Seed yield (kg/ha)



Kharif seasons, 2 per cent DAP and 0.2 per cent borax when sprayed in combination (S_3) recorded higher seed yield than spraying DAP and borax alone and control (no spray). Combined spray of 2 per cent DAP and 0.2 per cent borax recorded 1424 kg ha^{-1} and 1258 kg ha^{-1} of seed yield over different phosphorus levels during **Rabi** and **Kharif** seasons respectively.

In both the seasons, interaction between P levels and foliar spraying of DAP and borax was not significant.

4.3.2. Stalk yield (Table 13 and 14)

Higher stalk yield was recorded in **Rabi** season than in **Kharif** season. Application of phosphorus increased the stalk yield significantly in both **Rabi** and **Kharif** season crops. Highest stalk yield was recorded at 90 kg P_2O_5 ha^{-1} which was at par with that obtained at 60 kg P_2O_5 ha^{-1} during **Rabi** and **Kharif** seasons. In both the seasons, stalk yield was less when P was not applied.

Foliar spraying of DAP at 2 per cent and borax at 0.2 per cent either alone or in combination had no marked influence on the stalk yield during **Rabi** and **Kharif** seasons.

There was no interaction effect between P levels and foliar spraying of DAP and borax in both the seasons.

4.3.3. Oil yield (Tables 13 and 14)

Higher oil yield was recorded during **Rabi** season than **Kharif** season. Application of 90 kg P_2O_5 ha^{-1} recorded

Fig.15. Oil content (%)

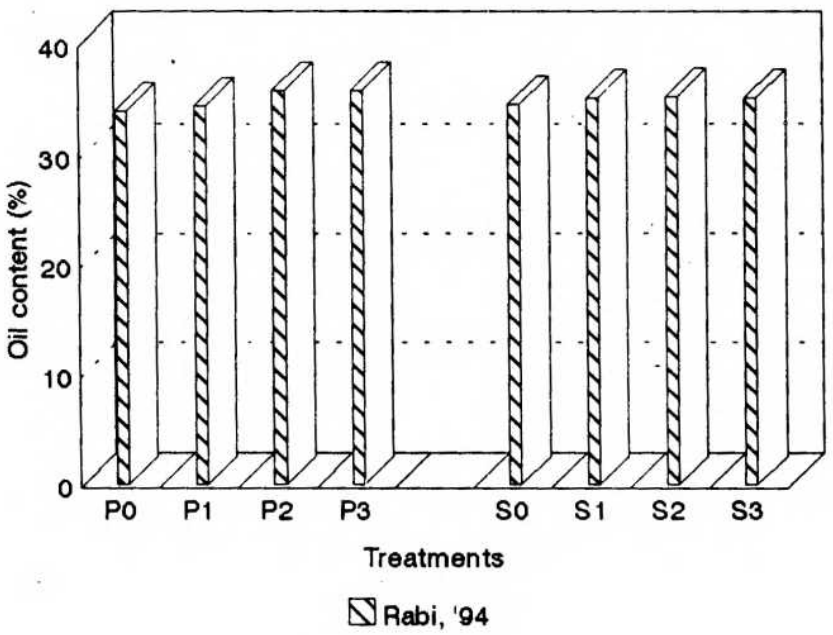
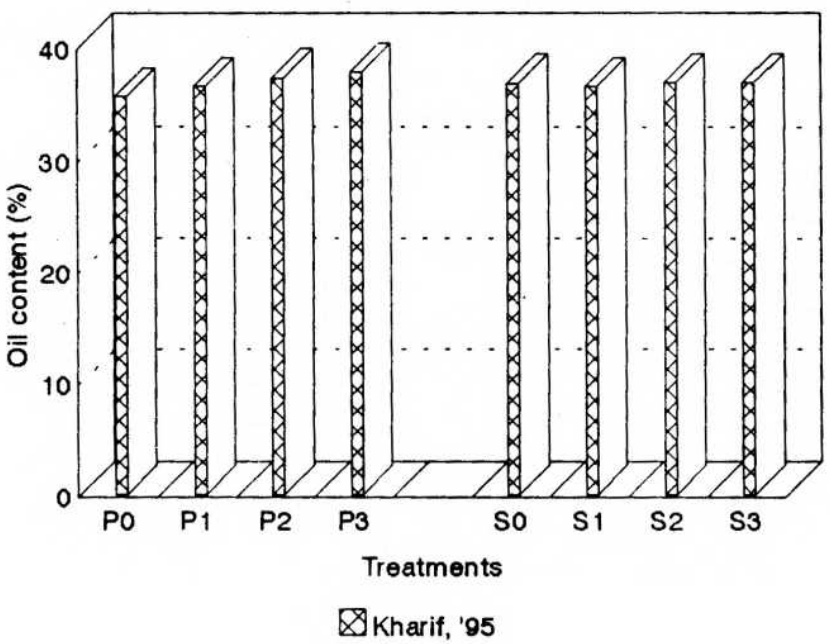


Fig.16. Oil content (%)



the highest oil yield followed by the application of 60 kg P_2O_5 ha^{-1} during both **Rabi** and **Kharif** seasons.

Among the spraying treatments 2 per cent DAP + 0.2 per cent borax combined spray recorded the highest oil yield. Interaction was not significant

4.4. QUALITY PARAMETER

4.4.1. Oil content (Table 13 and 14; Fig. 15 and 16)

Seed oil content was favourably influenced by phosphorus application. During **Rabi** season, application of 90 kg P_2O_5 ha^{-1} resulted in higher oil content of 35.87 per cent and application of 60 kg P_2O_5 ha^{-1} recorded 35.82 per cent oil. Similarly in **Kharif** season also the highest oil content of 37.71 per cent was recorded at 90 kg P_2O_5 ha^{-1}. Application of 30, 60 and 90 kg P_2O_5 ha^{-1} was superior to control.

There was no significant effect on the seed oil content due to foliar application of DAP (2 per cent) and borax (0.2 per cent) in both the seasons.

In both the seasons interaction between P levels and foliar spraying treatments remained insignificant.

4.5. NUTRIENT UPTAKE

Uptake of plant nutrients such as N, P and K were analysed based on their content and dry matter production and the results are presented.

Table 15. Uptake of N (kg/ha)

Treatments	Rabi, '94		Kharif, '95	
	30 DAS	60 DAS	30DAS	60DAS
P_0	4.27	37.87	4.18	34.28
P_1	6.75	49.38	6.63	48.50
P_2	7.0	55.63	6.98	54.2
P_3	7.15	56.10	7.09	56.15
SEd	0.24	3.0	0.10	1.08
CD(P=0.05)	0.49	6.13	0.20	2.20

Table 16. Uptake of P(kg/ha)

Treatments	Rabi, '94		Kharif, '95	
	30 DAS	60 DAS	30DAS	60DAS
P_0	0.77	4.64	0.72	4.14
P_1	1.07	6.05	1.05	5.80
P_2	1.58	8.13	1.48	7.85
P_3	1.64	9.22	1.55	8.20
SEd	0.05	0.40	0.04	0.16
CD(P=0.05)	0.10	0.82	0.08	0.33

Table 17. Uptake of K (kg/ha)

Treatments	Rabi, '94		Kharif, '95	
	30DAS	60DAS	30DAS	60DAS
P_0	11.15	39.35	10.35	36.30
P_1	12.32	53.15	11.75	49.20
P_2	13.80	59.55	13.25	52.63
P_3	14.20	60.03	13.60	53.33
SEd	0.41	1.91	0.46	0.55
CD(P=0.05)	0.84	3.90	0.95	1.11

Table 18. Uptake of N, P and K (kg/ha) at 90 DAS

Treatments	Rabi, '94			Kharif, '95		
	N	P	K	N	P	K
P_0	46.73	6.45	42.32	45.20	6.38	44.62
P_1	66.93	9.83	69.55	61.48	9.05	62.35
P_2	73.18	13.02	76.45	67.17	12.83	66.20
P_3	73.72	14.83	77.45	68.33	14.63	67.32
SEd	1.96	0.50	2.04	2.11	0.64	1.71
CD(P=0.05)	4.0	1.02	4.17	4.31	1.31	3.49
S_0	66.9	10.88	65.35	58.75	10.20	60.23
S_1	63.25	10.83	66.28	61.30	10.85	58.93
S_2	65.05	11.18	67.50	62.70	10.65	61.10
S_3	65.35	11.25	66.65	59.43	11.18	60.25
SEd	1.96	0.50	2.04	2.11	0.64	1.71
CD(P=0.05)	NS	NS	NS	NS	NS	NS
P x S						
SEd	3.92	1.00	4.08	4.22	1.29	3.42
CD(P=0.05)	NS	NS	NS	NS	NS	NS

4.5.1. Nitrogen (Table 15 and 18)

Uptake of N was significantly influenced by the levels of phosphorus. During **Rabi** season, higher N uptake was recorded at 90 kg P_2O_5 ha^{-1} followed by 60 kg P_2O_5 ha^{-1}. Uptake of N was less when phosphorus was not applied at all stages. Similar trend was observed during **Kharif** season also.

There was no significant influence on the N uptake during both the seasons due to foliar spraying of 2 per cent DAP and 0.2 per cent borax either alone or in combination.

Interaction between different levels of phosphorus and foliar spraying of DAP and borax was also not significant in both **Rabi** and **Kharif** seasons.

4.5.2. Phosphorus (Table 16 and 18)

Application of phosphorus had favourably influenced the P uptake. Among the different levels of phosphorus tried, higher P uptake was recorded in treatments applied with 90 kg P_2O_5 ha^{-1} followed by 60 kg P_2O_5 ha^{-1} at all stages during both **Rabi** and **Kharif** seasons. The uptake of P was less when P was not applied.

Phosphorus uptake was not increased with DAP at 2 per cent and borax at 0.2 per cent foliar spray either alone or in combination.

There was no interaction between P levels and foliar sprayings in both the seasons.

4.5.3. Potassium (Table 17 and 18)

Uptake of K was also influenced by phosphorus. During **Rabi**, '94, application of 90 kg P_2O_5 ha^{-1} resulted in higher K uptake at all stages followed by 60 kg P_2O_5 ha^{-1}. Similar trend was observed during **Kharif** season also.

There was no significant influence on the uptake of K at 90 DAS by foliar application of DAP and borax either alone or in combination during both **Rabi** and **Kharif** seasons.

In both the seasons interaction effect remained non significant.

4.6. AVAILABLE NUTRIENTS IN SOIL

Available nutrients in soil **viz.**, N, P and K were analysed at post harvest stage and results are presented.

4.6.1. Nitrogen (Table 19)

The available soil N was not significantly influenced by the levels of phosphorus applied during both **Rabi** and **Kharif** seasons.

Foliar spraying of DAP at 2 per cent and borax at 0.2 per cent either alone or in combination also had no effect on the available N.

Interaction effect was also not significant during **Rabi** and **Kharif** seasons.

Table 19. Available N, P and K in soil (Kg/ha) at post harvest stage

Treatments	Rabi, '94			Kharif, '95		
	N	P	K	N	P	K
P_0	144.75	10.20	439.75	130.00	9.92	371.0
P_1	142.75	16.58	432.75	125.35	17.18	368.0
P_2	140.25	17.20	436.83	128.13	18.03	365.3
P_3	138.75	19.53	429.25	125.5	19.25	363.0
SEd	3.12	0.43	7.13	2.45	0.37	6.22
CD(P=0.05)	NS	0.88	NS	NS	0.75	NS
S_0	141.37	15.82	433.50	126.85	16.32	365.9
S_1	141.12	15.95	434.75	127.00	16.05	366.6
S_2	140.63	15.65	432.25	127.30	16.07	368.0
S_3	143.38	16.08	438.0	128.00	15.93	365.8
SEd	3.12	0.43	7.13	2.45	0.37	6.22
CD(P=0.05)	NS	NS	NS	NS	NS	NS
P x S						
SEd	6.24	0.88	14.25	4.89	0.75	12.44
CD(P=0.05)	NS	NS	NS	NS	NS	NS

4.6.2. Phosphorus (Table 19)

Application of phosphorus had increased the soil available P. During **Rabi** season, application of 90 kg P_2O_5 ha^{-1} and 60 kg P_2O_5 ha^{-1} resulted in higher available P than 30 kg P_2O_5 ha^{-1} and control. In **Kharif** season also similar trend was noticed.

Soil available P status was not influenced by the foliar spraying treatments during **Rabi** and **Kharif** seasons.

In both the seasons, interaction effect was not significant.

4.6.3. Potassium (Table 19)

Different levels of P application did not significantly influence the soil available K in both the seasons.

Foliar spraying of 2 per cent DAP and 0.2 per cent borax had no significant effect on the available K.

Interaction between P levels and foliar spraying of DAP and borax was also not significant. Similar results were obtained in both **Rabi** and **Kharif** seasons.

4.7. ECONOMICS

4.7.1. Gross return (Table 20 and 21)

Gross return was high with 90 kg P_2O_5 ha^{-1} + 2 per cent DAP and 0.2 per cent borax combined spray (T_{16}) followed by 60 kg P_2O_5 ha^{-1} + 2 per cent DAP and 0.2 per cent borax combined spray (T_{15}). Gross returns of Rs.23175/-

Table 20. Economics - **Rabi**, '94.

Treatment	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net Return (Rs/ha)	BC Ratio
P_0S_0	6962	15315	8353	2.20
P_1S_0	7487	18600	11113	2.48
P_2S_0	8012	19140	11128	2.39
P_3S_0	8537	20385	11848	2.39
P_0S_1	7357	16800	9443	2.28
P_1S_1	7882	19575	11693	2.48
P_2S_1	8407	21180	12773	2.52
P_3S_1	8932	21570	12638	2.41
P_0S_2	7184	17070	9886	2.38
P_1S_2	7709	20145	12436	2.61
P_2S_2	8234	21375	13141	2.60
P_3S_2	8759	21600	12841	2.47
P_0S_3	7424	18210	10786	2.45
P_1S_3	7949	21015	13066	2.64
P_2S_3	8474	23070	14596	2.72
P_3S_3	8999	23175	14176	2.58

(Data not statistically analysed)

Seed : Rs. 120.00/kg
DAP : Rs. 10.02/kg
P_2O_5 as SSP : Rs. 17.50/kg
Borax : RS. 36.00/kg
Sunflower grain rate : Rs. 15.00/kg

Table 21. Economics - **Kharif**, '95

Treatments	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	BC Ratio
P_0S_0	6962	13230	6268	1.90
P_1S_0	7487	16035	8548	2.14
P_2S_0	8012	17745	9733	2.21
P_3S_0	8537	18150	9613	2.13
P_0S_1	7357	15015	7658	2.04
P_1S_1	7882	17190	9308	2.18
P_2S_1	8407	18630	10223	2.22
P_3S_1	8932	19035	10103	2.13
P_0S_2	7184	15060	7876	2.10
P_1S_2	7709	17205	9496	2.23
P_2S_2	8234	18975	10741	2.30
P_3S_2	8759	19245	10486	2.20
P_0S_3	7424	15825	8401	2.13
P_1S_3	7949	18630	10681	2.34
P_2S_3	8474	20385	11911	2.41
P_3S_3	8999	20625	11626	2.29

(Data not statistically analysed)

Seed : Rs. 120.00/kg
DAP : Rs. 10.02/kg
P_2O_5 as SSP : Rs. 17.50/kg
Borax : RS. 36.00/kg
Sunflower grain rate : Rs. 15.00/kg

and Rs.20625/- were obtained from 90 kg P_2O_5 ha^{-1} + 2 per cent DAP and 0.2 per cent borax spray during **Rabi** and **Kharif** seasons respectively.

4.7.2. Net return (Table 20 and 21)

Highest net return was obtained with 60 kg P_2O_5 ha^{-1} + 2 per cent DAP and 0.2 per cent borax spray (T_{16}) during both **Rabi** and **Kharif** seasons. Net returns obtained from 60 kg P_2O_5 ha^{-1} + 2 per cent DAP and 0.2 per cent borax spray were Rs.14596/- and Rs.11911/- during **Rabi** and **Kharif** seasons respectively. Net returns of Rs.14176/- and Rs.11626/- were obtained with 90 kg P_2O_5 ha^{-1} + 2 per cent DAP and 0.2 per cent borax combined spray (T_{16}).

4.7.3. B:C ratio (Table 20 and 21)

The highest B:C ratio was obtained with the application of 60 kg P_2O_5 ha^{-1} + 2 per cent DAP and 0.2 per cent borax combined spray (T_{15}) followed by 30 kg P_2O_5 ha^{-1} + 2 per cent DAP and 0.2 per cent borax combined spray (T_{14}) during both **Rabi** and **Kharif** seasons. Application of 60 kg P_2O_5 ha^{-1} along with 2 per cent DAP and 0.2 per cent borax foliar spray resulted in 2.72 and 2.41 B:C ratios during **Rabi** and **Kharif** seasons respectively. The B:C ratios at 30 kg P_2O_5 ha^{-1} + 2 per cent DAP and 0.2 per cent borax combined spray (T_{14}) were 2.64 and 2.34 during **Rabi** and **Kharif** seasons.

4.7.4. Physical optimum and economic optimum

Physical optimum level = 84.9 kg P_2O_5 ha^{-1}

Economic optimum level = 71.4 kg P_2O_5 ha^{-1}

DISCUSSION

CHAPTER V

DISCUSSION

Field experiments were conducted during **Rabi**, '94 and **Kharif**, '95 to study the effect of different levels of phosphorus and foliar application of diammonium phosphate and borax on the yield and seed setting of sunflower hybrid MSFH-8 under irrigated conditions. Experimental results are discussed in this chapter.

5.1. GROWTH ATTRIBUTES

5.1.1. Plant height

Plant height is an indicator of growth performance of the crop, as influenced by environmental and management factors. Higher doses of phosphorus (90 kg and 60 kg P_2O_5 ha^{-1}) increased the plant height over the lower doses. The higher level of P might have improved the nutrient uptake in the plant resulting in an increase in metabolic activities which led to the increased growth of plants. The lowest level (0 kg P_2O_5 ha^{-1}) accounted for minimum plant height. This might be due to starvation of sunflower to phosphorus which retarded the growth of crop at every stage of its life cycle. Increase in plant height due to phosphorus application was reported by Chaniara **et al.** (1989) and Prabhuraj **et al.** (1993).

Foliar application of DAP and borax had no effect in increasing the plant height. Boron application to the foliage of sunflower crop did not significantly influence

the growth characters (Hanumantha Rao and Vidyasagar, 1981a).

5.1.2. Stem girth

Stem girth is also an indication of the plant growth. Phosphorus application influenced the girth of the stem. But the effect was significant at 60 DAS during **Rabi** season and 90 DAS during **Kharif** season. Similar increase in stem girth with an increase in level of phosphorus was reported by Mukundan (1972) and Somasundaram (1979). Foliar spraying of 2 per cent DAP and 0.2 per cent borax did not influence the stem girth at 90 DAS.

5.1.3. Leaf area index (LAI)

Leaf area index determines the total photosynthesizing area available to the plant and the quantum of source that would be ultimately available for translocation to the sink. In the present study, application of higher levels of P increased the LAI. Similar results were obtained by Varghese **et al.** (1976a) and Shanmugam (1994).

5.1.4. Dry matter production

Dry matter production of a crop reflects its efficiency of utilization of available resources such as solar energy, moisture and nutrients. The dry matter production increased with an increase in P level. Higher levels of P application increased the available P in soil and uptake by plants. Inorganic P is very essential for

energy transformation processes involving ATP and ADP during photosynthesis. Hence, the increased uptake of P might be responsible for increased rate of photosynthesis resulting in higher DMP. Similar increase in DMP with higher levels of P application was reported by Ateeque **et al.** (1993) and Narsi Reddy and Madan Mohan Reddy (1993). The dry matter production was not influenced by the spraying treatments in later stages of crop growth. The interaction between P levels and spraying remained non significant.

Thus it is evident that application of phosphorus had favourably influenced the plant height, stem girth, DMP and LAI.

5.2. YIELD ATTRIBUTES

5.2.1. Capitulum diameter

Diameter of the head is considered to be one of the most important factors determining the yield of sunflower crop. In the present study, increased diameter of the head was observed at 60 kg P_2O_5 ha^{-1} and 90 kg P_2O_5 ha^{-1}. Phosphorus is an important plant nutrient and is a component of nucleic acids, coenzymes, nucleotides, phosphoproteins, phospholipids and sugar phosphates. An adequate supply of P early in the life of a plant is important in the development of its reproductive parts (Tisdale **et al.**, 1993). Similar results of increased head diameter with phosphorus application was obtained by Narsi Reddy and Madan Mohan Reddy (1993) and Prabhuraj **et al.** (1993).

Diammonium phosphate at 2 per cent and borax at 0.2 per cent spraying had no effect in increasing the diameter of the head. Interaction between P levels and foliar spraying of DAP and borax was also non significant. Leela Rani and Madan Mohan Reddy (1993) reported that application of boron 0.4 per cent spray had no discernible influence on head diameter.

5.2.2. Number of seeds per head

Application of higher levels of P resulted in higher number of seeds per head. Phosphorus is considered essential for seed formation. An adequate supply of phosphorus might have resulted in the increased synthesis of photosynthates and might have produced higher floret number. Similar results of increased number of seeds by the application of increased doses of P was reported by Chaniara **et al.** (1989) and Megur **et al.** (1993).

Diammonium phosphate 2 per cent spray increased the number of seeds per head over control. As P is very essential for seed development, supply of P during reproductive phase of the crop might have resulted in proper seed development and also increased the number of seeds per head.

Similarly borax spraying also resulted in increased number of seeds per head. Shatilov and Ikonnikov (1970) found that boron increased the pollen viability and fertilising capacity of pollen. Bobek and Kovacik (1972)

reported that boron and calcium helped in better pollen germination and resulted in higher seed set. Thus the increased number of seeds might be due to better pollen germination, increased pollen viability and fertilising capacity of pollen. Increased number of seeds per head with foliar application of borax was reported by Hanumantha Rao and Vidyasagar (1981a).

Interaction between P levels and spraying DAP and borax was not significant.

5.2.3. Percentage of filled seeds

Application of 90 kg P_2O_5 ha^{-1} and 60 kg P_2O_5 ha^{-1} had increased the percentage of filled seeds. Application of higher levels of P might have resulted in higher uptake of P. Phosphorus is essential for seed development. Hence, higher P availability might have increased the percentage of filled seeds. Increased percentage of filled seeds with higher doses of P was reported by Narsi Reddy and Madan Mohan Reddy (1993).

Diammonium phosphate at 2 per cent spray also increased the percentage of filled seeds. Phosphorus applied through foliage might have stimulated the seed formation and increased the seed filling percentage supplementing the soil available P. Increased number of filled seeds per head with foliar application of two per cent ammonium dihydrogen orthophosphate was reported by Kene **et al.** (1990).

Foliar spraying of borax at 0.2 per cent also increased the percentage of filled seeds. This might be due to better pollen germination, increased pollen viability and fertilising capacity of pollen. Increased number of filled seeds per head with borax dusting was reported by Tufail Ahmed Khan **et al.** (1990). Hanumantha Rao and Vidyasagar (1981a) and Leela Rani and Madan Mohan Reddy (1993) reported an increase in number of filled seeds with borax spray.

5.2.4. Test weight

Phosphorus application at higher levels increased the test weight. Weight of seeds is influenced by the availability of nutrients. Higher nutrient availability might have resulted in higher uptake of nutrients and increased the test weight. Increase in test weight with P application was reported by Khokani **et al.** (1993).

Foliar spraying of DAP and borax did not influence the test weight. Leela Rani and Madan Mohan Reddy (1993) found no significant influence on the test weight with spraying of 0.4 per cent boron.

Thus it is clear that P application had significant effect on yield attributing characters like diameter of the head, number of seeds per head, percentage of filled seeds and test weight.

Spraying 2 per cent DAP and 0.2 per cent borax alone as well as in combination had significant influence

only on the number of seeds per head and percentage of filled seeds.

5.3. YIELD

5.3.1. Seed yield

Seed yield was increased with increasing P levels. Higher seed yield was recorded at 90 kg P_2O_5 ha^{-1} which was at par with that at 60 kg P_2O_5 ha^{-1}. A good supply of P has been associated with root growth which might have absorbed plant nutrients well and influenced the yield components. Increase in diameter of head, number of seeds per head, filling percentage and test weight had finally reflected in seed yield. Increase in seed yield with the application of P was reported by several workers (Chaniara **et al.**, 1989; Thosar **et al.**, 1991; Naphade and Naphade, 1992; Ateeque **et al.**, 1993; Megur **et al.**, 1993 and Vivek **et al.**, 1993).

Seed yield was also increased with the foliar spraying of DAP alone, borax alone and DAP + borax combined spray over control. The increase in seed yield might be due to increased number of seeds per head and filling percentage.

Foliar application of DAP during flowering might have helped in seed development and increased the number of seeds per head and filling percentage which ultimately increased the seed yield.

Borax spraying also increased the seed yield which might be due to better pollen germination, increased pollen viability and pollen fertilisation as reported by Shatilov and Ikonnikov (1970) and Bobek and Kovacik (1972). Increase in seed yield of sunflower with borax dusting was reported by Tufail Ahmed Khan **et al.** (1990). Leela Rani and Madan Mohan Reddy (1993) reported an increase in seed yield of sunflower with borax spraying.

Borax and DAP when applied in combination had better effect on the yield and yield attributing characters like number of seeds per head and percentage of filled seeds. Interaction between P levels and foliar spraying of 2 per cent DAP and 0.2 per cent borax was not significant.

5.3.2. Stalk yield

Stalk yield was increased with the increased doses of P. Increased stalk yield might be due to increased growth attributing characters.

Foliar spraying of 2 per cent DAP and 0.2 per cent borax had no significant effect on the stalk yield. Soil applied nutrients might be sufficient for the growth of the plants. Interaction between P levels and foliar spraying of DAP and borax was not significant.

5.3.3. Oil yield

Application of higher doses of phosphorus increased the oil yield. This increase in oil yield was due to increased seed yield and oil content.

Foliar spraying DAP and borax also increased the oil yield. This was due to increased seed yield.

5.4. QUALITY PARAMETER

5.4.1. Oil content

Phosphorus application to sunflower was observed to increase the oil content in seed. Phosphorus plays an important role in carbohydrate metabolism and helps in the conversion of carbohydrates into oil (Bonner and Varner, 1965). Increase in oil content with the increased doses of P was reported by Naphade and Naphade (1992).

Spraying of 2 per cent DAP and 0.2 per cent borax had no significant influence in seed oil content. Oil content of the seed was not significantly affected due to urea + DAP spray (Sagare **et al.**, 1986). Leela Rani and Madan Mohan Reddy (1993) reported that there was no significant influence on seed oil content with boron dusting and 0.4 per cent boron spraying.

5.5. NUTRIENT UPTAKE

Uptake of N, P and K was higher at 90 kg P_2O_5 ha^{-1} and 60 kg P_2O_5 ha^{-1}. Higher level of P application increased the available P content in soil. A good supply of P had been associated with root growth which might have facilitated the uptake of the nutrients in adequate amounts resulting in better plant growth and higher dry matter production.

The increased uptake of nutrients might be due to increased accumulation of dry matter and nutrient content. Increased nutrient uptake with increased doses of P was reported by Naphade and Naphade (1992).

Foliar application of 2 per cent DAP and 0.2 per cent borax had no significant influence on the nutrient uptake. Interaction between P levels and foliar spraying of DAP and borax was also not significant.

5.6. ECONOMICS

Application of 60 kg P_2O_5 ha^{-1} along with 2 per cent DAP and 0.2 per cent borax combined spray recorded the highest net returns of Rs.14596/- and Rs.11911/- during **Rabi** and **Kharif** seasons respectively which was followed by the application of 90 kg P_2O_5 ha^{-1} + 2 per cent DAP and 0.2 per cent borax spray. The B:C ratios obtained with 60 kg P_2O_5 ha^{-1} + 2 per cent DAP and 0.2 per cent borax were higher (ie., 2.72 and 2.41 during **Rabi** and **Kharif** seasons respectively) followed by 30 kg P_2O_5 ha^{-1} + 2 per cent DAP and 0.2 per cent borax spray which recorded B:C ratios of 2.64 and 2.34 during **Rabi** and **Kharif** seasons.

SUMMARY AND CONCLUSION

CHAPTER VI

SUMMARY AND CONCLUSION

Field experiments were conducted at Tamil Nadu Agricultural University Farm, Coimbatore during **Rabi**, '94 and **Kharif**, '95 to study the effect of phosphorus and boron on the yield and seed setting of sunflower hybrid (MSFH-8) under irrigated conditions.

The experiments were laid out in a factorial randomised block design with two factors, each with four levels. ie. Different levels of phosphorus (0, 30, 60 and 90 kg P_2O_5 ha^{-1}) and different spraying treatments (no spray, 2 per cent DAP spray, 0.2 per cent borax spray and combination of 2 per cent DAP and 0.2 per cent borax).

Observations on growth parameters such as plant height, stem girth and DMP were recorded on 30, 60 and 90 DAS. Leaf area index was recorded on 30 and 60 DAS. Yield components like diameter of the capitulum, number of seeds per capitulum, percentage of filled seeds and test weight were recorded. Seed and stalk yield were also recorded.

The plant samples of the crops were analysed for N, P and K contents at various stages (30, 60 and 90 DAS) for working out the nutrient uptake. Soil samples were taken and analysed for its available N, P and K at pre-sowing and at post harvest stages of the crop. Oil content of the seed was also estimated. The data were subjected to statistical

analysis. The results of the study are summarised below and conclusions drawn.

Phosphorus application had influenced the growth parameters favourably. Maximum plant height was recorded at 90 kg P_2O_5 ha^{-1} which was at par with that at 60 kg P_2O_5 ha^{-1} at all stages of the crop during both the seasons (except at 30 DAS during **Rabi**). Application of 90 kg P_2O_5 ha^{-1} recorded highest stem girth at all stages during both the seasons. Leaf area index was higher with 90 kg P_2O_5 ha^{-1} which was at par with that at 60 kg P_2O_5 ha^{-1} at 30 and 60 DAS in **Rabi** and at 30 DAS in **Kharif**. Higher dry matter production was obtained with 90 kg P_2O_5 ha^{-1} and was on par with that recorded at 60 kg P_2O_5 ha^{-1} at all stages of the crop in which observations were taken during both the seasons.

Growth parameters were not influenced by foliar spraying of DAP 2 per cent, borax 0.2 per cent alone or DAP 2 per cent + borax 0.2 per cent in combination during both the seasons.

Yield components such as diameter of the capitulum, number of seeds per capitulum, percentage of filled seeds and test weight were favourably influenced by P application. Application of 60 kg P_2O_5 ha^{-1} and 90 kg P_2O_5 ha^{-1} resulted in higher diameter of the capitulum during both **Rabi** and **Kharif** seasons. Number of seeds per head and test weight were higher at 90 kg P_2O_5 ha^{-1} and at par with

that obtained at 60 kg P_2O_5 ha^{-1}. Application of 90 kg P_2O_5 ha^{-1} recorded highest percentage of filled seeds followed by 60 kg ha^{-1} during both the seasons.

Spraying DAP and borax either alone or in combination had no effect on the capitulum diameter and test weight. But all the spraying treatments increased number of seeds per capitulum and seed filling percentage over no spray. Among the spraying treatments DAP + borax combined spray (S_3) recorded higher number of seeds per head and percentage of filled seeds.

Higher seed yield was obtained during **Rabi** than **Kharif** season. Highest seed yield was recorded at 90 kg P_2O_5 ha^{-1} which was at par with that obtained at 60 kg P_2O_5 ha^{-1} during both the seasons. Spraying DAP + borax in combination (S_3) recorded higher yield than spraying DAP (S_1) and borax alone (S_2) and no spray (S_0). Diammonium phosphate 2 per cent and borax 0.2 per cent spraying were on par during both the seasons.

Application of 90 kg P_2O_5 ha^{-1} produced higher stalk yield and was at par with 60 kg P_2O_5 ha^{-1} during **Rabi** and **Kharif** seasons. Spraying treatments did not influence the stalk yield.

Oil content was increased with P application. Application of 90 kg P_2O_5 ha^{-1} recorded highest seed oil content (**Rabi** - 35.87 per cent; **Kharif** 37.71 per cent) which was on a par with that at 60 kg P_2O_5 ha^{-1}. Foliar spraying

of DAP and borax had not influenced the oil content.

Uptake of N, P and K were higher with 90 kg P_2O_5 ha^{-1} followed by 60 kg P_2O_5 ha^{-1} at all stages during both the seasons. Nutrient uptake was not affected by spraying DAP and borax.

Available N and K were not influenced significantly either by levels of P or by spraying treatments at post harvest stage during both the seasons. Available P content was increased with an increase in level of P during both the seasons. Soil available nutrient status was not affected by spraying treatments.

In general **Rabi** season crop experienced favourable weather conditions and performed better than **Kharif** crop.

Net return and B:C ratio were higher with 60 kg P_2O_5 ha^{-1} combined with 2 per cent DAP and 0.2 per cent borax spraying (T_{15}) treatment. Net returns of Rs.14596/- and Rs.11911/- were obtained with 60 kg P_2O_5 ha^{-1} + 2 per cent DAP and 0.2 per cent borax combined spray.

Based on the results obtained from the study, application of 60 kg P_2O_5 ha^{-1} along with 2 per cent DAP + 0.2 per cent borax combined spray is recommended to the hybrid sunflower MSFH-8 to obtain highest net return.

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