EFFECT OF IRRIGATION LAYOUTS AND FOLIAR SPRAYING OF NUTRIENTS AND GROWTH HORMONE ON SOYBEAN (*Glycine max* (L.) Merr.)

Thesis submitted in part fulfillment of the requirements for the degree of
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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF IRRIGATION LAYOUTS AND FOLIAR SPRAYING OF NUTRIENTS AND GROWTH HORMONE ON SOYBEAN (*Glycine max* (L.) Merr.)"** submitted in part fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY** (Agriculture) in Agronomy to the Tamil Nadu Agricultural University, Coimbatore is a record of bonafide research work carried out by Ms.**R.KALPANA** 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 work has not been published in part or full in any scientific or popular journal or magazine.

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Kalpana

(R.KALPANA)

ABSTRACT

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Effect of irrigation layouts and foliar spraying of nutrients and growth hormone on soybean (*Glycine max* (L.) Merr.)

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Field experiments were conducted during *kharif,* 1999, summer and *kharif* seasons of 2000 in soybean (CO 1) at Tamil Nadu Agricultural University, Coimbatore with an objective to explore the possibilities of improving the seed yield and quality of soybean through irrigation layouts and foliar spraying of nutrients and growth hormone. The main plot treatments included three irrigation layouts viz., flat beds, flat ridges and furrows, ridges and furrows. The subplot treatments comprised of water spraying, DAP 2 %, DAP 2% + KCl 1%, DAP 2% + KCl 1% + boron 0.2%, DAP 2% + KCl 1% + boron 0.2% + NAA 40 ppm. These treatments were laid out in split plot design with three replications.

The growth components were higher under ridges and furrows sprayed with a combination of DAP 2%, KCl 1% and boron 0.2%. All the physiological parameters were influenced favourably by the ridges and furrows receiving a combined spray of DAP 2% and KCl 1%. The yield components were significantly influenced by foliar spray of DAP

2%, KCl 1%, boron 0.2% and NAA 40 ppm. The grain yield was significantly higher under ridges and furrows followed by flat ridges and furrows. The combined foliar spraying of DAP 2%, KCl 1%, boron 0.2% and NAA 40 ppm recorded higher grain yield closely followed by the combined application of DAP 2%, KCl 1% and boron 0.2%. The haulm yield and harvest index were however not significantly influenced by the different treatments. The seed protein content was significantly higher with foliar spray of DAP and the oil content was higher with the combination of DAP 2%, KCl 1% and boron 0.2%. The nutrient uptake was significantly higher with combination of DAP and KCl.

The water consumption was lower under flat ridges and furrows followed by ridges and furrows and the flat beds consumed more water. The water use efficiency was higher under flat ridges and furrows and lower with flat beds. Among the foliar sprays, the treatments including KCl recorded higher water use efficiency and highest values under the combination of DAP 2%, KCl 1%, boron 0.2% and NAA 40 ppm. Comparing the different treatment combinations, ridges and furrows sprayed with DAP 2%, KCl 1% and boron 0.2% registered higher values of net returns and B:C ratio followed by the combination of DAP 2%, KCl 1%, boron 0.2% and NAA 40 ppm under the same layout.

It can be concluded that raising soybean under ridges and furrows is the best option considering the yield and net returns. Foliar spraying of DAP 2%, KCl 1%, boron 0.2% and NAA 40 ppm is the best combination in terms of grain yield and net returns. Comparing the different treatments, adoption of ridges and furrows sprayed with a combination of DAP 2%, KCl 1%, boron 0.2% and NAA 40 ppm is the best option.

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INTRODUCTION

CHAPTER I

INTRODUCTION

Soybean (*Glycine max* (L.) Merr.), the unique pulse cum oilseed crop is considered as a proteinaceous boon from heaven and poor man's meat to vegetarians since it is nutritionally comparable to animal protein except for the methionine content. It is a miracle golden bean of 20^{th} century which possesses the potential of revolutionising the Indian economy by correcting the health of human beings (with its wide spectrum of chemical composition) and soil (increasing the C:N ratio). On an average soybean seed contains 41 per cent protein, 21 per cent oil and 11 per cent soluble carbohydrate (Openshaw and Hadley, 1984). Both soybean oil and protein play an important role in the world market. In India during 1997-98 soybean was exported to the tune of 25 lakh tonnes, worth Rs.2,500 crores (Anon, 1999).

Eventhough soybean was initially grown in scattered areas in India, increase in area and production over the past three decades has been spectacular. However the productivity of soybean in India is relatively low (1022 kg ha^{-1}) in comparison with other countries in the World. It has occupied 2.25 per cent of total cropped area in India.

The growth of soybean is greatly affected by moisture availability at critical growth stages since this crop is being sensitive to both excess and low soil moisture conditions. Thus the irrigation layouts have a definite effect on the growth and yield of the crop (Nalawade and More, 1993). The adoption of an appropriate irrigation layout not only helps to minimise the water use by the crop but also to ensure optimum moisture environment and to overcome problems of water-logging.

Even after considerable research on the crop management practices and the fertiliser application, the yield of soybean remains low, the reasons are probably the excessive vegetative growth, poor harvest index, flowering and pod setting or the shedding of premature pods. Although legumes like soybean are efficient in nitrogen fixation, developing pods will be deprived of nitrogen availability on account of early leaf senescence.

In general, pulses are low yielders than cereals, because pulses are rich in protein, consuming more energy to synthesize protein than carbohydrate. It has been estimated that one gram glucose can give rise to 0.8 g carbohydrate but on average only about 0.5 g protein and even less oil (Singh, 1991). Such large concentration of protein in seeds may require early mobilisation of leaf protein, thus impairing their capacity for prolonged photosynthesis. The maintenance of symbiotic nitrogen fixation in root nodules also competes for energy during this stage. Moreover, due to the indeterminate growth habit of pulse crops, flowering, pod formation and seed setting stages overlap and necessitate the translocation of nutrients from the source equally to all the sink components viz., flowers, pods and seeds. Imbalance in nutrient translocation results in either flower drop, immature pod drop or ill filling of seeds. Thus, foliar nutrition with all the essential nutrients at this stage becomes critical and is the only option for mediating the proper source-sink relationship.

Also maintenance of optimum soil moisture supply during this stage becomes imperative for efficient grain filling which is made possible only by the adoption of appropriate irrigation layout. A significant effect of irrigation method on germination and growth of soybean was reported by Al Salmani *et al.* (1991). Ingle *et al.* (1999) studied the effect of land configuration on yield of soybean and reported that maximum grain yield could be obtained under ridges and furrows.

The beneficial effect of foliar spraying of different nutrients and plant hormones to increase soybean yield by enhancing pod formation and seed filling have been reported by many research workers (Ravankar *et al.*, 1998; Dhopte and Suradkar, 1998). Moreover adverse soil conditions drastically affect nutrient availability at critical stages in soybean and foliar feeding can effectively cure these nutrient deficiencies.

The favourable effect of foliar application of either urea 2% or DAP 2% (Kalarani and Jeyakumar, 1998) and that of combined application of DAP 2% + KCl 1% (Ramesh, 1999) on efficient seed filling and increased grain yield have been observed. The deleterious effects of water stress on crop growth can be minimised by nutrient and plant hormonal application which are able to protect the crop from moisture stress by conserving adequate water in plants and minimise yield reduction. The water demand of the crop at critical stages can also be considerably reduced by potassium nutrition, which maintains higher leaf water potential (Velu, 1999). Legumes have high boron requirement and suffer more frequently from boron deficiency. Also a synergistic relationship of boron with potassium (Sakal *et al.*, 1988) and nitrogen (Gary Gascho, 1994) have been reported.

The use of plant growth regulators, which can improve the physiological efficiencies of plants offer a significant role in increasing the yield of pulses. Furthermore the plant growth regulators like Napthalene Acetic Acid (NAA) are known to increase flowering, pod setting and grain filling in soybean (Deotale *et al.*, 1998). The combined foliar application of the nutrients and NAA is found to have an enhanced effect than individual applications and also considered economic (Thangaraj, 2000).

Keeping this in view, the present investigation was carried out to study the effect of irrigation layouts and foliar spraying of nutrients and plant hormones on soybean with the following objectives:

1. To study the effect of different irrigation layouts on growth, yield and quality of soybean.
2. To study the response of soybean to foliar spray of different combination of nutrients.
3. To study the effect of foliar spray of different nutrients in combination with growth hormone on growth, yield and quality of soybean.
4. To work out the economics of irrigation layouts and foliar sprays on soybean.

REVIEW OF LITERATURE

CHAPTER - II

REVIEW OF LITERATURE

Soybean, grown under optimum set of management conditions has high yielding capacity. Water management has become the most indispensable factor for augmenting the crop productivity especially in a crop like soybean because of its high susceptibility to both water stress and water logging at various growth stages. This warrants the need for adoption of suitable irrigation method which creates a favourable soil moisture environment for maximising yield by conserving soil moisture, reducing weed growth and improving crop growth and yield promotional factors. In the present day of water scarcity, optimum method of irrigation plays a vital role in economising the irrigation water and enhancing crop yield. Many research findings also confirm considerable saving in irrigation water through adoption of appropriate field layout. Ill-filling of pods is a major problem in increasing soybean productivity which can be offset through foliar application of nutrient combinations and growth regulating substances. The present investigation was carried out to find out the performance of soybean under different irrigation methods and foliar spraying of nutrients and growth hormones. The response of soybean and other field crops to different irrigation methods and foliar nutrition is reviewed in this chapter.

2.1. SIGNIFICANCE OF IRRIGATION METHODS

Under irrigated condition check basin method of irrigation is commonly followed which is not favourable for conserving moisture when water is limited for irrigation.

Hence for efficient utilisation of limited water supply, suitable land management practice was felt necessary. Ridges and furrows have several distinct advantages like reduced contact area of water on land surface there by reducing puddling and crusting of the soil and evaporation losses (Michael, 1978).

Suitable land configurations help in enhancing time of concentration, absorption and storage of water, thus useful for the crops (Mahendrapal *et al.*, 1990). Moreover this method also favours optimum availability of soil moisture with uniform flow of water and reduced weed competition as compared to check basins. Also the loose and porous soil heap under ridges and furrows was found to provide better aeration, microbial activity and drainage which gave increased individual plant yield and per hectare yield as compared to other methods (Rangaraj, 1991). Thus ridges and furrows method provides an environment favourable for maximising crop yield (Azam Ali *et al.*, 1993). Methods involving ridges and furrows and narrow or broad bed furrow also appear to possess many of the essentials for increasing water use efficiency (Vairavan, 1993).

2.1.1 EFFECT OF IRRIGATION METHODS ON CROP GROWTH

Soybean, being sensitive to moisture, the persistence of wetness within rooting zone adversely affects the crop growth. Method of sowing therefore plays a great role in influencing the seed germination and thereby affecting plant growth and yield. A significant effect of irrigation method on germination and growth of soybean was reported by Al Salmani *et al.* (1991). Effect of varying land management practices on morpho-physiological characters of irrigated soybean was studied by Jayapaul *et al.*

(1995). The results of the study indicated that there was an increase in leaf area index, relative leaf water content, transpiration rate and stomatal conductance due to broad bed furrow method while the leaf temperature was lower. Better conservation of soil moisture and efficient utilisation of stored soil moisture, were also reported to have favourably influenced these characters. Influence of planting systems on physiological parameters, like leaf area index, leaf area duration and dry matter production and yield of chickpea was studied by Sheikh and Mungse (1998) and they reported that ridges and furrows system yielded better results than flat beds.

2.1.2. EFFECT ON YIELD PARAMETERS AND YIELD

2.1.2.a. Soybean

The interaction between supply and demand for water is the main determinant of dry matter production and yield of crops. Mehar Singh *et al.* (1986) opined that method of sowing plays a great role in influencing the seed germination and thereby affecting plant population and yield. They conducted a study on the method of sowing soybean, and obtained maximum seed yield under ridges and furrow sowing (2103 kg ha^{-1}) and on an average this method gave 36.1 per cent more grain yield over the flat beds. Effect of land management on yield attributes and yield of irrigated soybean was studied by Jayapaul *et al.* (1996). The results of the finding revealed that there was an increase in number of pods per plant and seed yield of soybean due to broad bed and furrow method of irrigation (1350 kg ha^{-1}) as compared to ridges and furrows (1259 kg ha^{-1}) and check-basin method (1169 kg ha^{-1}). They attributed the well-aerated and friable condition of the soil, better drainage, aeration and uptake of nutrients under this method, to be the primary reason for the commendable increase in number of pods per plant and seed yield.

Similar influence of irrigation layout on soybean yield was reported by Willis *et al.* (1999) on a hard setting alfisol. Ingle *et al.* (1999) studied the effect of land configuration on yield of soybean and reported that maximum grain yield of soybean could be obtained under ridges and furrows sowing (1841 kg ha^{-1}). On an average this treatment gave 8.54 and 16.29 per cent higher than the yield obtained under sowing in broad bed and furrow and flat bed methods respectively.

2.1.2.b. Pulse crops

Pigeonpea grown on ridges gave higher seed yield than on flat beds under lowland soils which become water logged in rainy season (Tripathi, 1987). In the alfisol with poor physical properties ridge and furrow system was observed to favour better growth of pigeonpea (Okada *et al.*, 1991). In a study on the effect of planting methods, cowpea produced lowest yield of 2.69 t ha^{-1} in flat beds and 2.81 t ha^{-1} in ridges and furrows (Lawand *et al.*, 1993).

The effects of irrigation layouts on grain yield of blackgram was studied by Vijayalakshmi and Rajagopal, (1994). They recorded mean seed yields of 1.06, 1.10 and 1.16 t ha^{-1} from check basin, ridges and furrows and flat ridges respectively. They reported that the higher water holding capacity of soil in combination with improved soil moisture status ultimately resulted in better seed development in blackgram. The effect of irrigation layouts on grain yield of greengram was studied by Vijayalakshmi and Rajagopal (1995) and they obtained highest seed yield by sowing in ridges and furrows followed by flat ridges which were significantly higher than yield obtained under check basin systems of irrigation.

Singh *et al.* (1998) quantified the effect of planting methods on productivity of pigeonpea and reported that planting pigeonpea on raised beds and ridges and furrows increased yield by 44 and 37 per cent over traditional flat bed method. They observed that ridge making loosened soil, increased infiltration and percolation of water and restricted water impounding in field. The response of cowpea and blackgram to different land management practices was studied by Somasundaram *et al.* (2000). The growth, yield attributes and yield were lowest in flat beds for both the crops mainly due to poor germination, growth and crop stand.

2.1.2.c. Groundnut

Patil (1989) evaluated the use of broad beds and furrows for irrigated groundnut on medium black soils. The results indicated that cultivation on broad beds markedly increased the number of effective pegs per hill and gave pod yields of 4.05 t ha^{-1} compared with 2.19 t ha^{-1} for control basins. Rao *et al.*, (1991) recorded dry pod yields of 2.9 t ha^{-1} in flat bed system and 4.8 t ha^{-1} in broad bed furrow system. The different planting layouts in groundnut was studied by Desai and Kenjale (1992) and they found that ridges and furrows produced the highest pod yield (2.75 t ha^{-1}) due to the favourable influence on yield characters, followed by broad bed and furrow (2.17 t ha^{-1}). Groundnut sown in ridges and furrow and broad bed furrow methods recorded higher yields over flat beds (Hadwani *et al.*, 1993; Bhoi *et al.*, 1993).

Relative efficiency of soil management practices studied on groundnut showed highest pod yield of 1707 kg ha^{-1} under beds and furrows, 1518 kg ha^{-1} under ridges and furrows and 1460 kg ha^{-1} under flat beds (Sandhya *et al.*, 1994). Patra *et al.* (1994) compared the yield of groundnut sown under different planting methods. They found that number of pods per plant, seeds per pod, pod and oil yields were highest in flat beds with earthing up as compared to flat beds without earthing up or broad bed and furrow method.

The impact of irrigation layout systems on yield of groundnut was studied by Rajagopal *et al.* (1995) and they found that the number of matured pods and hundred pod weight were significantly higher under ridges and furrow method compared to other layouts. They recorded pod yields of 1.76, 1.93 and 1.84 t ha^{-1} under basin, ridges and furrows and flat ridges and furrows systems respectively. The yield increase under ridges and furrows were due to optimum soil moisture with uniform flow of water, lesser weed competition because of lesser area of wetted periphery and enhanced yield attributes. Vairavan and Sankaran (1996) compared the different seeding methods on nutrient uptake and yield of groundnut. They observed that among the seeding methods, ridges and furrow method recorded higher uptake of nutrients and seed yield (1720 kg ha^{-1}) compared with broad bed and furrows (1495 kg ha^{-1}) and check basins (1313 kg ha^{-1}).

Subrahmaniyan *et al.* (1999) reported that pod yields of groundnut obtained with ridges and furrows were significantly higher over yields under flat beds. The effect of field layouts on growth and yield of groundnut was studied by Pawar *et al.* (2000) and they reported pod yield increase of 7.5 % under broad bed and furrow method than that of flat bed. They found that the environmental conditions in respect of soil water plant relationship largely influenced the pod formation and development in broad bed furrow, which also provided loose soil mass, adequate soil moisture and air.

2.1.3. EFFECT OF IRRIGATION METHODS ON WATER USE EFFICIENCY

2.1.3.a. Soybean

The impact of different land configuration treatments, including flat beds, broad bed and furrow and raised beds on water use efficiency of soybean was studied by Sharma (1996) and reported that WUE was highest under raised beds followed by broad bed and furrows. The Water use efficiency of soybean was greater in a broad bed furrow layout with irrigation at 0.6 IW/CPE ratio than flat bed system (Bharambe *et al.*, 1999).

2.1.3.b. Groundnut

The different methods of irrigation for groundnut were evaluated by Patel *et al.* (1995) and they reported that the water use efficiency was highest with sowing and irrigation in furrows than flat beds. Rajagopal *et al.* (1995) studied the impact of irrigation layouts on water consumption in groundnut and reported that ridges and furrows followed by flat ridges and furrows were effective in reducing the total water consumption as compared to check basin system. Among the three land management systems viz., ridges and furrows, check basin and corrugated furrows studied in groundnut, better conservation of soil moisture and efficient utilisation of stored soil moisture could be observed under ridges and furrows, resulting in higher number of pods per plant as well as pod yield (Ramasamy *et al.*, 1999). Effect of land configuration on water use efficiency in groundnut was studied by Meyyazhagan *et al.* (1999) and the results revealed that groundnut raised in ridges and furrows resulted in higher water use efficiency compared to flat beds.

2.1.5. EFFECT ON ECONOMIC PERFORMANCE

Jayapaul *et al.* (1996) reported highest net returns and B:C ratio under broad bed and furrow and ridges and furrow methods as compared with check basin method. Jain and Dubey (1998) compared the different systems of irrigation in soybean and recorded highest seed yield (1482 kg ha^{-1}), straw yield (1995 kg ha^{-1}), net returns (Rs.9075 ha^{-1}) and B:C ratio (2.43) by sowing the crop in ridges and furrows.

Heatherly *et al.* (2000) compared the economic performance of soybean grown in furrow irrigation with flood irrigation and found that though yields from furrow irrigated crops were significantly higher, net returns were similar under both methods. Somasundaram *et al.* (2000) who studied the response of cowpea and blackgram to different land management practices recorded highest B:C ratio of 2.7 under ridges and furrows. The B:C ratios of flat beds and flat ridges and furrows were almost equal.

2.2. INFLUENCE OF FOLIAR NUTRITION ON CROP GROWTH AND YIELD

During certain critical stages of crop growth, the metabolic demands for mineral nutrients may temporarily exceed the capacity of root absorption. Such stress periods can be overcome by foliar feeding of fertilisers by which, nutrients are supplied to plant directly without spending energy for their transport and without any loss in transit. Thus foliar fertilisation does not replace soil fertilisers but efficiently supplement them. Selvam *et al.* (1989) reported that top dressing of 10 kg N ha^{-1} to groundnut as foliar spray of 2% urea yielded 2.82 t ha^{-1} while the same as soil application produced 2.46 t ha^{-1}.

Balusamy and Meyyazhagan (2000) opined that the greatest difficulty in supplying N, P and K through foliar sprays is in the application of adequate amounts without severely burning the leaves and without an unduly large volume of solution or more number of spray operations. Thangaraj (2000) stressed the need for mixing foliar nutrients with growth regulators and pesticides, which will save a lot of time, energy and money. Moreover the efficiency of soil applied nutrients is low due to various losses and fixation in soil. Foliar nutrition is designed to eliminate the problems of fixation and immobilisation.

Ill-filling of pods is one of the major disorders affecting the yield potential of soybean. Physiological disorders caused by environmental stresses accelerate ill-filling. Gary Gascho (1994) observed that soybean requires much of their nutrition late in the season, in reproductive stages, for optimum seed set and development. Many investigators have reported the beneficial effect of different nutrients and hormones on the increase in soybean yield by enhancing the pod formation and seed filling. (Ravankar *et al.*, 1998; Dhopte and Suradkar, 1998). Several studies indicate that similar responses are often obtainable with foliar applications (Ingle *et al.*, 1999; Kannan, 1986).

2.2.1. EFFECT OF FOLIAR SPRAY OF DIAMMONIUM PHOSPHATE

2.2.1.1.SOYBEAN

Foliar spray of DAP increased the 100 seed weight and hence seed yield in soybean (Upadhyay *et al.*, 1988). Foliar application of phosphorus during pod formation increased yield by 10 per cent in soybean (Suo and Wu, 1990). Application of 40 kg P_2O_5 ha^{-1} to soybean as basal with 2 % P_2O_5 spray on 25th day produced higher grain and haulm yield which was on par with yield obtained with basal application of 80 kg P_2O_5 ha^{-1} (Raghavan, 1992).

Nitrogen needs of soybean plant during the pod-filling stages are great and if N supply is not adequate during this stage, seed number and seed size will be reduced, possibly due to early senescence (Gary Gascho, 1994). In a study on phosphorus fertilising technique for soybean, Purushothaman *et al.* (1994) observed that basal application of 60 kg P_2O_5 ha^{-1} and 20 kg P_2O_5 by foliar application in three splits gave the highest seed yields and net returns compared with 80 kg P_2O_5 ha^{-1} applied as basal.

Effect of foliar application of nitrogen and phosphorus on dry matter production and grain yield of soybean was studied by Ravankar *et al.* (1998) and realised the significance of DAP foliar spray in increasing the grain yield over control. Kalarani and

Jeyakumar (1998) studied the effect of nutrients and NAA spray on physiological changes in soybean which was given as foliar sprays of 1% urea, 2 % DAP, 2 % potassium sulphate, 0.2 % boron or 0.04 % NAA. The results revealed that urea and DAP were the most effective treatments in reducing leaf senescence by increasing chlorophyll and soluble protein contents. Foliar sprays of urea or DAP also increased the grain yield significantly followed by K_2SO_4, boron and NAA.

Ingle *et al.* (1999) studied the effect of foliar spray of urea on soybean and reported significant response of soybean grain yield to foliar application of N at flowering stage. This was explained by the maximum uptake of mineral nitrogen at early flowering and better nutrient balance in the plants by supplying nutrients through foliage, leading to increased yield components. Soil application of 20 kg N: 64 kg P_2O_5: 40 kg K_2O ha^{-1} followed by foliar spray of 2 % DAP at flowering and pod development stages could increase soybean yield significantly than soil application of recommended fertilisers alone (Chandrasekharan *et al.*, 1999).

2.2.1.2. REDGRAM

Solaiappan and Ramiah (1990) studied the effect of different combinations of foliar sprays on seed yield of redgram. They reported that foliar spray of 3 % DAP yielded slightly higher yield than a combined spray of 1.2 % urea + 8.6 % SSP and significantly higher than the individual applications of either urea or SSP. The positive response of redgram to foliar spray of DAP was also confirmed by Upadhyay *et al.* (1992). The influence of foliar application of 3 % DAP on yield of redgram was studied by Solaiappan *et al.* (1994) and found that highest grain yield was obtained by basal application along with 3 % DAP foliar spray.

2.2.1.3. BLACKGRAM

Two per cent DAP solution to blackgram is recommended to be sprayed twice, once at flower initiation and another 15 days later which was found to increase the grain yield of blackgram (Ponnusamy *et al.*, 1999). Top dressing of 12.5 kg N ha^{-1} twice followed by foliar spraying of DAP and KCl on 55 and 65 days after sowing was found to double the yield of blackgram by two times over basal application of recommended fertilisers alone (Chandrasekharan *et al.*, 1999).

Subramani and Solaimalai (2000) stated that the poor production potential of blackgram is attributable to poor photosynthetic efficiency, lack of partitioning of photosynthates to pods and seed setting. They reported the favourable influence of foliar application of nutrients with DAP 1 % + urea 0.5 % + MgSO4 0.5 % + ZnSO4 0.25 % on grain yield. This treatment also recorded higher LAI, CGR, NAR and RGR which was followed by foliar spray of DAP 2 % + NAA 40 ppm along with seed treatment with nutrients.

2.2.1.4. GREENGRAM

Samiullah *et al.* (1986) studied the impact of foliar application of 2 kg P_2O_5 as sodium di-hydrogen orthophosphate, at flower initiation stage on mungbean. They reported that foliar spray of mungbean significantly increased the number of pods per plant, pod length, number of seeds per pod, seed protein content and gave seed yields of 1.32 t ha^{-1} compared with 1.02 t ha^{-1} without foliar application of P. The response of mungbean to soil and foliar application of P fertilisers was compared by Pandrangi *et al.* (1991). It was reported that, seed yield of mungbean was 1.01 t ha^{-1} with soil applied P, 0.84 t ha^{-1} with foliar applied P and 1.26 t ha^{-1} with soil and foliar applications. Patel and Patel (1994) reported that summer greengram with the application of 20 kg N + 40 kg P_2O_5 ha^{-1} (recommended rate) and foliar application of urea (1.5 %) + DAP (0.5 %) at 30 and 40 DAS gave seed yields of 1.74 and 1.67 t ha^{-1}.

Although pulse crops like greengram are efficient in nitrogen fixation, developing pods will be deprived of nitrogen on account of early leaf senescence. Suresh *et al.* (2000) suggested that foliar application of nitrogen at later stages of crop growth to be one of the possible ways of overcoming this problem. They reported that foliar application of urea (2 %) twice (at flowering and pod development) significantly increased grain yield of greengram by 25.6 per cent over control. The increase in grain yield was due to timely delivery of nutrients to site of photosynthesis. Selvi *et al.*, (2000) studied the effect of 2 % DAP as foliar spray at flowering and 15 days later on seed yield of greengram and obtained a seed yield of 535 and 470 kg ha^{-1} with DAP spray and basal application respectively. They found that during the floral and pod development stages, the demand for N is more (because of more competition between the sink organs), which could be met out by foliar application of the same during flowering and pod development.

2.2.1.5. CHICKPEA

Raghuwanshi *et al.* (1995) obtained highest seed yield of chickpea when P as DAP was applied 50 % as basal and 50 % as foliar application on 35 and 55 DAS.

2.2.1.6. COWPEA

The effect of soil and foliar application of phosphorus on seed yield of cowpea was also studied by Gill *et al.* (1971). Foliar application of P_2O_5 gave better response than soil application and 25 kg P_2O_5 ha^{-1} as foliar spray at flowering was better than 50 kg P_2O_5 ha^{-1} as soil application.

Response of cowpea to foliar nutrition of urea and DAP sprayed each at 2 % concentration on 20 and 30 days after sowing was studied by Srinivasan and Ramasamy (1992). Spraying 2 % DAP produced similar yield to soil application of N and P and higher yield than urea spray. They also reported that inhibition of nodulation observed through soil application of N will not take place if N is applied through foliar spraying and the plants will be able to derive simultaneous benefits of both elemental and combined nitrogen.

2.2.1.7. GROUNDNUT

Selvam *et al.* (1989) reported that top dressing of 10 kg N ha^{-1} to groundnut as 2 percent urea spray yielded 2.82 t ha^{-1} while the same as soil application gave 2.46 t ha^{-1} only.

2.2.2. EFFECT OF FOLIAR SPRAY OF POTASSIUM

2.2.2.1.SOYBEAN

Potassium plays an important role in controlling the movement of water from leaves and maintain water balance by better absorption of nutrient through leaves under moisture stress condition (Perumal and Pasupathi, 1994). Soybean accumulates 60 to 80 per cent of its K needs after flowering and higher crop yields are placing an increasing demand on the available soil K (Synder and Ashlock, 1996).

Rajagopal and Velu (1995) studied the impact of soil and foliar application of potassium on physiology and productivity of soybean. Potassium was considered to be a better osmoticum for stomatal regulation and for the maintenance of better internal water balance in tissues. The transpiration rate and stomatal diffusive rate were favourably influenced by potassium. Foliar application of 0.5 % KCl at peak flowering stage of soybean maintained higher tissue water, which was followed by split application of K. However split application of K produced 330 kg ha^{-1} increased yield and 0.5 % KCl spray resulted in an yield increase of 215 kg ha^{-1} over control.

Foliar application of potassium as 2 % potassium sulphate spray on soybean was found to have a significant influence on yield attributes like pod number and pod filling thereby favouring increased yield than control (Kalarani, 1991). Foliar application of 0.5 per cent KCl recorded higher seed yield in soybean since K induces drought tolerance, maintains cell turgidity and better transport of carbohydrates (Elamathi, 1997). The impact of foliar application of potassium chloride (0.5 %) or NAA (40 ppm) was compared and found that crop growth and yield of soybean can be increased by KCl spray under water stress conditions by maintaining tissue water potential and preventing water loss (Velu, 1999). It also increased the oil content significantly.

2.2.2.2. BLACKGRAM

The efficacy of foliar application of potassium on grain and protein yield of blackgram was studied by Velu and Srinivasan (1984). They reported that two foliar sprays of 1% KCl to blackgram increased seed yield by 10.2 per cent. The increased yield was due to an increase in number of clusters and pods per plant. Ramamoorthy *et al.* (1995) studied the response of rainfed blackgram (*Phaseolus mungo*) to foliar nutrition of potassium, with or without the basal application of N, P and K. Foliar application of 1 % KCl at flowering and pod formation stages and basal application of 12.5 kg N and 37.5 kg P ha^{-1} recorded seed yield of 553 kg ha^{-1} followed by foliar application of 1 % K_2SO_4 + basal application (536 kg ha^{-1}).

2.2.2.3. GREENGRAM

Sadasivam *et al.* (1990) studied the effect of potassium nutrition on growth and yield of greengram. Potassium was applied as soil application at 25 kg K_2O ha^{-1} and as foliar spray at 1 % KCl and 1 % K_2SO_4 at flowering. It was evident from the study that foliar application of potassium significantly improved the leaf moisture status, dry matter accumulation, seed yield and harvest index than the soil application. Seed yields of 809, 833, 870 and 890 kg ha^{-1} was recorded with no K, 25 kg K_2O ha^{-1}, 1 % KCl spray and 1% K_2SO_4 spray at flowering respectively.

The influence of foliar application of KCl, KH_2PO_4, urea and growth regulators on the yield components and yield of greengram, was studied by Gomathi (1996). She found that foliar application of urea, KCl and KH_2PO_4 at one per cent concentration at flowering and pod filling increased the dry matter accumulation and yield.

2.2.2.4. REDGRAM

The effect of foliar application of potassium on the growth and yield components of pigeonpea was studied by Ravindranath *et al.* (1985) and they reported higher yield in response to foliar application of potassium.

2.2.2.5. CHICKPEA

Naik *et al.* (1993) studied the response of chickpea to foliar nutrition with water, 2 % urea, 2 % triple super phosphate or 2 % potassium sulphate. They reported highest grain yield, straw yield, pods per plant and grains per pod with foliar application of 2 % potassium sulphate.

2.2.2.6. GROUNDNUT

Moisture stress at any growth stage was found to reduce the pod yield of groundnut and this reduction could be made good by supplementing with 0.5 % potassium spray at peak flowering stage (Mohandass *et al.*, 1987). Chandrasekar *et al.* (1994) reported that foliar application of 1 % K_2O to groundnut not only increased the pod and haulm yield but also reduced incidence of 'tikka' leaf spot in groundnut.

2.2.3. EFFECT OF COMBINED APPLICATION OF MACRONUTRIENTS

2.2.3.1. SOYBEAN

Garcia and Hanway (1976) registered a significant yield increase in soybean due to foliar spraying of N,P,K and S during pod filling stage. Chamber (1987) reported that foliar application of nitrogen, phosphorus and potassium at 7 to 14 days interval to soybean crop increased the seed protein and oil content. Among different foliar spray treatments tested, a combination of DAP 2 % and KCl 1 % along with benzyladenine 25 ppm sprayed twice produced marked increase in growth characters, yield attributes, yield and seed quality in soybean (Ramesh, 1999). The response of soybean to foliar application of 3:8:15 NPK fertiliser dose at early vegetative stage was evaluated and significant yield increases were recorded (Haq and Mallarino, 2000).

2.2.3.2. CHICKPEA

Srivastava and Srivastava (1994) studied the effect of foliar sprays of nutrients on chickpea and reported that among foliar sprays of water, 2 % urea, triple super phosphate or potassium sulphate, application of 2 % urea gave the highest seed yield.

2.2.3.3. GREENGRAM

Kuppuswamy *et al.* (1992) reported a favourable influence of seed pelleting on greengram with a combination of 5 % DAP and 5 % KCl which resulted in increased germination, number of effective nodules per plant, pods per plant and seed yield.

2.2.4. EFFECT OF BORON APPLICATION

2.2.4.1. SOYBEAN

Recently the value of boron application to soybean has been reported in several studies. The physiological causes of responses to boron application are that boron increases the plasticity of cell walls of flower parts, thus decreasing pod abortion. It increases the pollen germination and also improves translocation of sugars in the plant as sugar-borate complexes. Boron injected directly into soybean plants increased the number of pods on lateral branches and yield (Gary Gascho, 1994). The effect of foliar application of boron as boric acid in soybean was studied by Garg *et al.* (1999). They reported an increase in number of leaves, branches, leaf area, and a sharp decline in flower drop through application of boron at 50.0 mg lit^{-1}. Yield attributes like pod set per plant, length of pod, number of seeds per pod and test weight, were also found to be maximum with boron application.

The influence of boron application to soybean in addition to the recommended dose of NPK fertilisers was evaluated by Sharma (1992) and it was found that seed yield of soybean was 1.46 t ha^{-1} with boron and 1.36 t ha^{-1} without boron. The susceptibility of soybean plants to boron deficiency was examined by Rerkasem *et al.* (1993) and they revealed that without boron, seed yield was depressed by 60 per cent in soybean. They also observed that B deficiency induced a localised depression of the internal surface of one or both cotyledons of some soybean seeds resembling the symptoms of "hollow heart" in groundnut seeds. However they reported that addition of boron decreased or eliminated the symptoms.

Boron application was also reported to influence the nodule development and nitrogen fixation (Yamagishi and Yamamoto, 1994). They found that when soybean plants were grown in boron-free medium, nodules were damaged and N fixation was affected and found that boron is important for development and N fixation of nodules. Datta *et al.* (1994) reported that boron application at 1mg kg^{-1} in deficient soils was found to be optimum for soybean. Balusamy *et al.* (1996) reported that boron application at 0.5 kg ha^{-1} produced higher seed yield (1428 kg ha^{-1}) as compared to control (1204 kg ha^{-1}) with recommended dose of fertilisers alone. Bhuiyan *et al.* (1996) studied the effect of boron on nodulation and yield of soybean and reported that boron increased nodule number, nodule weight, shoot and root dry weights and grain yields.

The favourable influence of foliar application of boron on yield of soybean was also reported by Dwivedi *et al.* (1990) and Sexena and Chandel (1997). Response of soybean to boron seed treatment was studied by Nedic *et al.* (1997) and observed significant yield improvement as a result of boron. Soybean seeds treated with 0.15 g B kg^{-1} seed produced yield of 21 per cent higher than control (Cui Xian, 1998). Patra (1998) reported that application of boron at 2.0 kg ha^{-1} as borax to soybean produced an yield increase of 900 kg ha^{-1}. Wankhade *et al.* (1998) found that application of boron alone gave the highest soybean seed yield as compared to the combined application of zinc, iron and boron. Thiyageshwari and Ramanathan (1999) studied the effect of foliar application of nutrients along with the recommended dose of nutrients on the dry matter production and yield of soybean. They reported that foliar application of NPK with MnSO4, ZnSO4, sodium molybdate and boron yielded the highest seed yield of 1832 kg ha^{-1} followed by foliar application of boron (1398 kg ha^{-1}) as against the recommended NPK (1225 kg ha^{-1}).

2.2.4.2. CHICKPEA

Sakal *et al.* (1990) studied the effect of boron application on chickpea under calcareous soils and recorded seed yield of 1.79 t ha^{-1} with boron applied at 3 kg ha^{-1} and 1.4 t ha^{-1} without boron. The yield response to boron application was greater on low boron soils. Srivastava *et al.* (1996) examined the cause of flower abortion and failure of pod set in chickpea and conclusively indicated that B deficiency is the primary causal factor for flower and pod drop in chickpea. The treatment receiving all other elements except boron produced pod and grain yields lower than the control, which received no nutrients. Sakal *et al.* (1998) observed that application of boron at 2 kg ha^{-1} to chickpea produced a seed yield response of 750 kg ha^{-1} and boron at 1 kg ha^{-1} to lentil increased seed yield by 300 kg ha^{-1}.

2.2.4.3. REDGRAM

Kalyani *et al.* (1993) studied the effect of foliar application of boron at 200, 300 or 400 ppm on 30, 60, 90 or 120 DAS on grain yield of pigeonpea and the yield response was noticed with increasing rates of boron upto 300 ppm and then decreased.

2.2.4.4. FRENCH BEAN

Effect of foliar spray of boron on flowering, fruiting and yield of french bean (*Phaseolus vulgaris*) was studied by Padma *et al.* (1989). They found that foliar sprays of 2.5 ppm boron twice on 20 and 40 DAS, increased the number of flowers and pods per plant and gave pod yields of 4.06 t ha^{-1} compared with 3.01 t ha^{-1} without boron.

2.2.4.5. GROUNDNUT

Chaudhry and Muhammed (1990) studied the effect of seed treatment of groundnut with 0.25 M solution of boric acid which recorded a seed yield of 1.65 t ha^{-1} as against 1.07 t ha^{-1} under control. The impact of boron on yield of groundnut was studied by Ramamoorthy and Sudarsan (1992) who observed that foliar spray of 0.25 % borax on 30 DAS along with 2.5 kg B ha^{-1} significantly increased the pod yield, test weight, seed protein and oil percentage of groundnut. Krishnappa (1993) also confirmed the favourable influence of boron application on groundnut along with recommended dose of NPK fertilisers.

Agasimani *et al.* (1993) found a significant yield increase in groundnut through soil application of 2.5 kg B ha^{-1} and a further increase in boron application decreased the pod yield. The seed oil content however increased upto 5 kg B ha^{-1}. The effect of boron fertiliser on yield and quality of groundnut was studied by Luo *et al.* (1994). They found that boron application decreased plant height but increased branches, total pods, fertile pods, double seed pods, 100 seed weight and plump pod rate, and also promoted uptake of N, P and K and the seed protein content.

Balerao *et al.* (1994) reported that foliar applications of 0.1 % borax at 40 and 55 DAS recorded the highest yield in groundnut. Yield increase was recorded in summer groundnut due to application of boron applied with N and P fertiliser (Mahakulkar *et al.*, 1994). Sahu *et al.* (1995) observed the favourable influence of boron in increasing pod yield, shelling percentage, oil content and oil yield in groundnut.

2.2.5. EFFECT OF BORON IN COMBINATION WITH MACRONUTRIENTS

2.2.5.1. SOYBEAN

An investigation conducted by Wu Wen Yi (1999) on factors causing non-podding of soybeans suggested that podding is strongly influenced by soil K and B availability and that a shortage of either would reduce pod formation. Results indicated that single application of K (150 kg KCl ha^{-1}) or B (7.5 kg borax ha^{-1}) had no significant effect on pod formation, but simultaneous application increased yield by 57 and 42 per cent in two test years. Hence an application of basal and top-dressing of KCl along with spraying of 0.2 % borax solution at peak flowering stage of soybean was recommended.

Gary Gascho (1994) reported that soybean requires much of their nitrogen and boron during reproductive stages, for optimum seed set and development. In a study conducted on the late-season fertilisation of soybean with nitrogen and boron he reported an increased soybean yield due to foliar application of nitrogen along with boron. Yield response of soybean to combined application of phosphorus, potash and boron along with rhizobium inoculation was studied by Bhuiyan *et al.* (1996). They observed 109 per cent increased yield over control with application of PKB + inoculum.

The efficacy of foliar application of polyfeed which contains N both in nitrate and ammoniacal forms, P as ortho phosphate and K as potassium nitrate and traces of micronutrients including boron, on soybean yield was studied by Jeyabal *et al.* (1999). The results showed that foliar spray of 1% polyfeed thrice produced higher soybean yield by 12.1 % over control which was attributed to the greater availability of nutrition from the foliar applied nutrients, especially during the pod formation stage.

2.2.5.2 CHICKPEA

The effect of boron application on chickpea was studied by Sakal *et al.* (1988) and they revealed that soil application of boron upto 2.5 kg B ha^{-1} increased the grain yields of chickpea and the magnitude of response in chickpea was much higher (63 %). A study on effect of boron with or without phosphorus and potash on yield and economic performance of chickpea was studied by Bhuiyan *et al.* (1999) and they obtained highest seed yield (1.52 t ha^{-1}) in the treatment receiving PKMoB + inoculum where the percentage seed increase was 204 over control. The PKB + inoculum recorded 141 per cent yield increase over control and the benefit cost ratio (BCR) for PKB was 6.49 indicating the better economic performance from application of boron with P and K.

2.2.5.3. BLACKGRAM

The effect of boron application in blackgram was studied by Sakal *et al.* (1988) and they revealed that soil application of boron upto 2.0 kg B ha^{-1} increased the grain yields of blackgram. Potassium-boron relationship studies in blackgram revealed that the grain yield response with boron application was much higher than K application and their relationship was found to be synergistic.

2.2.5.4. GROUNDNUT

Malewar *et al.* (1992) evaluated the effect of phosphorus with and without boron on yield of groundnut and obtained highest yield of 3.12 t ha^{-1} from boronated SSP and lowest from DAP alone (2.36 t ha^{-1}). According to Mahakulkar *et al.* (1994), highest dry matter and dry pod yield of groundnut was obtained through application of boron at 10 kg ha^{-1} along with nitrogen and phosphorus at 25 and 50 kg ha^{-1} respectively.

2.2.5.5. SIRATRO

Effect of foliar application of boron with macronutrients sprayed at flower initiation and fortnight later on seed and stover yield of siratro (*Macroptelium atropurpureum*) was studied by Dwivedi *et al.* (1998). The results indicated that foliar spraying of KNO_3 + borax and P_2O_5 + borax each at 2 kg ha^{-1} yielded 50.7 and 48.2 kg ha^{-1} as compared to 33.9 kg ha^{-1} under control.

2.2.6. EFFECT OF NAPTHALENE ACETIC ACID

2.2.6.1. SOYBEAN

Foliar spray of soybean with NAA at 6.25 ppm increased grain yield by 40 per cent over control which appeared to be associated with the increase in number of seeds per pod (Sarma and Shah, 1979). Spraying of NAA at flowering was reported to reduce the flower abscission and increase the average pod weight in soybean (Merlo *et al.*, 1987). Foliar application of NAA (40 ppm) at peak flowering stage of soybean recorded the highest yield of 1709 kg ha^{-1} and was on par with application of CCC (200 ppm) sprayed at flowering stage (1643 kg ha^{-1}) (Cherukara, 1987).

Ravikumar and Kulkarni (1988) opined that application of NAA increased the 100 seed weight in soybean. Sharma *et al.* (1990) compared the efficacy of foliar application of different growth regulators and concluded that triacontanol, NAA, cytokinins, atonik and water spraying gave seed yields of 477, 463, 492, 477 and 434 kg ac^{-1} respectively. No differences in test weight, protein and oil content were observed. Beneficial responses of soybean to hormone sprays were reported by Shinde *et al.* (1991).

Chaplot *et al.* (1992) studied the effect of foliar application of NAA at 10 ppm on growth, yield attributes and yield of soybean, sprayed at flower initiation and grain filling stages. The results showed that the seed yield (1550 kg ha^{-1}) increased by 23 per cent over control (1260 kg ha^{-1}) which was reported to be due to production of higher number of branches per plant, pods per plant and pod length. The application of NAA might have induced large number of new sinks leading to greater activity of carboxylating enzymes and rate of protein synthesis, which resulted in higher photosynthetic rate, translocation and accumulation of metabolites in the sink and eventually greater seed production.

Soybean crop which received NAA at 50 ppm as seed soaking registered a yield increase of 12.67 per cent over control (Deotale *et al.*, 1998). This was attributed to the superior values of morpho-physiological components like plant height, number of leaves and branches, leaf area, dry matter accumulation and the increased source-sink relationship in plants treated with NAA.

2.2.6.2. BLACKGRAM

In a study on improvement of physiological parameters of blackgram in response to application of 30 ppm NAA, Baghel and Yadava (1994) reported that NAA was superior to gibberellic acid and IAA in enhancing LAI, NAR, CGR and photosynthetic efficiency. Seed yields of blackgram were also highest with NAA application as compared to gibberellic acid, IAA and control. Lakshmamma and Rao (1996) studied the influence of NAA at 20 ppm on blackgram sprayed twice at 50 % flowering and a week later and found that NAA application decreased flower drop and increased seed yield. It also increased plant height, dry weight and chlorophyll content. Mahla *et al.* (1999) reported the favourable influence of 20 ppm NAA on blackgram, which resulted in increased plant height, branches per plant, chlorophyll content, nodulation and dry matter production. Significant improvement in pods per plant, grains per pod and test weight were also observed with NAA application.

2.2.6.3. GREENGRAM

Foliar application of NAA on greengram at anthesis stage and 10 days later increased the number of pods per plant, seeds per pod and test weight and gave seed yields of 849 kg ha^{-1} compared with 694 kg ha^{-1} without NAA (Sharma *et al.*, 1989). Seed soaking of greengram with NAA at 10^{-6} M concentration was found to have a favourable influence of plant height, dry weight, flowering and pod setting than IBA, distilled water and control treatments (Patel and Saxena, 1994). The seed yield with NAA was 11.7 q ha^{-1} as against 10.5 q ha^{-1} in control. The increased growth and yield caused by NAA was due to a positive interaction of exogenously applied hormone with the endogenous one (synergistic effect) which in turn favourably affected the physiological processes.

Das and Prasad (2000) studied the response of greengram to foliar application of NAA at different concentrations. They reported that application of NAA at 40 ppm produced dry matter yield of 5.4 g $plant^{-1}$ more than that of control. The increase in grain yield with the application of 40 and 20 ppm NAA was 25.6 and 14.6 per cent over control. The yield attributes (number of pods per plant and number of grains per pod), stover yield and nutrient uptake was also significantly improved in response to application of NAA.

2.2.6.4. REDGRAM

Meena and Goswami (1992) found that seed soaking of redgram with10^{-6} M NAA increased nodulation by delaying the decrease in N fixing efficiency at flowering. The favourable influence of NAA sprayed at 40 ppm, on seed yield of redgram was reported by Shinde and Jadhav (1994). They reported an increase in number of pods, which was attributed to decreased shedding of flowers and immature pods during the early development. However Gita Ghosh (1996) studied the effect of foliar spray of NAA on redgram and blackgram and reported that NAA application did not significantly affect nodulation in both the crops.

2.2.6.5. LABLAB BEAN

Uddin *et al.* (1996) studied the effect of spraying NAA at 250 or 500 ppm on 37, 57 and 72 DAS on growth and pod yield of lablab bean. They recorded a per plant yield of 1.19 and 1.23 kg with 250 and 500 ppm NAA respectively compared with control (0.89 kg). The application of 250 ppm NAA produced the highest number of primary (5.3 pl^{-1}) and secondary (22.8 pl^{-1}) branches and number of pods per plant were highest with 500 ppm NAA.

2.2.6.6. CHICKPEA

Foliar spray of 1000 ppm cytozyme, 20 ppm NAA and 50 ppm TIBA on chickpea sprayed at 45 DAS gave seed yields of 2.02, 1.89 and 1.82 t ha^{-1} compared with 1.60 t ha^{-1} for the control (Patil *et al.*, 1990). Effect of NAA on growth, development, flowering behaviour and yield of chickpea was studied by Upadhyay (1994). Seed yield was increased by NAA sprayed at 20 ppm followed by 300 and 200 ppm KNO_3 sprayed at bud initiation and pod formation stages, which resulted in increased flower numbers and retention.

2.2.6.7. GROUNDNUT

Kelaiya *et al.* (1991) reported that groundnut sprayed with 40 ppm NAA gave a pod yield of 1.06 t ha^{-1} compared with 0.98 t ha^{-1} for spraying with 500 ppm CCC and 0.97 t ha^{-1} with water spraying as a result of increased LAI, plant dry weight, shelling percentage and test weight. Nawalagatti *et al.* (1991) reported significant improvement in the growth parameters of groundnut including LAI, dry matter production, NAR and CGR and pod yields as a result of NAA foliar application at 20 ppm at 45 DAS.

Patil and Morey (1991) reported that NAA sprayed at 10 ppm, 35 DAS produced higher dry pod yield than control in groundnut. Response of groundnut to foliar application of NAA on 30 and 60 DAS was confirmed by an increased yield of 1.77 t ha^{-1} as compared to 1.62 t ha^{-1} under control (Tripathy *et al.*, 1994).

2.2.6.8. FABA BEAN

Effect of foliar application of NAA before flowering in *Vicia faba* showed that NAA reduced flower drop and pod drop from 76 per cent in the control to 43 per cent thereby increasing seed and pod yields (Khare *et al.*, 1993).

2.2.7. EFFECT OF MACRONUTRIENTS WITH NAA

2.2.7.1. SOYBEAN

Foliar spraying of NAA at 50 % flowering with or without added urea and potash increased the number of flowers formed and hence seed yield (Sarmah and Dey, 1986). Foliar spraying of 2 per cent DAP along with 40 ppm NAA resulted in increased pods per plant, better pod filling and hence improved grain yield (Cherukara, 1987). Influence of foliar spray of nutrient complexes (containing macro and micronutrients) along with plant growth regulators on yield of soybean was studied by Shukla *et al.* (1997) and the results revealed a positive effect of foliar application of nutrients with NAA on yield components and yield of soybean.

Response of soybean to foliar sprays of nutrients ($(NH_4)_2NO_3$, KH_2PO_4, KNO_3 at 0.5 % each) and NAA at 20 ppm, either alone or in combination was studied by Dhopte and Suradkar (1998). The results revealed that a combination of KNO_3 at 0.5 % and NAA at 20 ppm foliar spray, yielded 9 % higher yield over the recommended fertiliser dose. They observed that the NAA sprays being cheaper than gibberellic acid can be recommended either with KNO_3 or $(NH_4)_2NO_3$ for maximum returns as against the full recommended dose. Fertiliser economy is a need of the day and additional sprays of nutrients and hormones which costs Rs. 800 ha^{-1} gives in return 200 kg ha^{-1} more yield over full recommended dose.

Plants adapt to water deficits by altering the physiological responses, when the plants are supplemented with foliar application of inorganic chemicals including the nutrients like potassium. The impact of foliar spraying of potassium chloride (0.5 %) and NAA (40 ppm) on the growth of soybean was studied by Velu (1999). The results revealed that foliar application of 0.5 % KCl or 40 ppm NAA improved the crop growth of soybean under water stress conditions by maintaining the tissue water potential either as an osmoregulant or by preventing water loss. It was also reported to increase the chlorophyll content and soluble protein content over unsprayed control due to higher leaf water potential maintained by the applied chemicals.

2.2.7.2. GREENGRAM

With recommended fertiliser rates, foliar application of 50 ppm TIBA or NAA or 2% urea or KNO_3 at pre flowering stage gave seed yields of 0.67, 0.66, 0.61 and 0.59 t ha^{-1} respectively compared with 0.55 t ha^{-1} for untreated control. (Kandagal *et al.*,1990). Foliar spraying of 3 % P_2O_5 and 100 ppm NAA on greengram resulted in highest total dry matter accumulation per plant and also seed yield and harvest index (0.79 q ha^{-1} and 28.7 % respectively). This was associated with a greater number of pods per plant and seeds per pod (Kalita *et al.*, 1995).

2.2.7.3. COWPEA

Influence of nitrogen and NAA on growth and yield parameters of cowpea was studied by Jain *et al.* (1995) and they reported that seed yield was highest with basal application of 40 kg N ha^{-1} along with foliar application of 45 ppm NAA at the start of flowering. A study was conducted on the effect of foliar spray of NAA and KNO_3 on growth and yield of cowpea, by Shinde and Jadhav (1995). They obtained highest yield of 1.53 t ha^{-1} through NAA application at 5 ppm and the mean seed yield was 1.03 t ha^{-1} in unsprayed crops and 1.42 and 1.29 t ha^{-1} in crops sprayed with NAA and KNO_3 respectively.

2.2.7.4. REDGRAM

Arunachalam *et al.* (1995) studied the effect of foliar application of redgram with 2 % DAP twice (once at flowering and second 15 days later) and foliar spray of 40 ppm NAA at 55 DAS which was compared with spraying 1 % KCl twice (55 and 70 DAS). The results showed that foliar application of 2 % DAP was found to give increased yield of 28.5 per cent over application of recommended fertilisers alone. This was closely followed by application of DAP and NAA foliar spray and the next best was KCl foliar spray. All the nutrients and NAA were applied as separate sprays.

Effect of potassium nitrate and NAA on growth and yield of redgram was studied by Jayarami Reddy *et al.* (2000). The foliar application of NAA 20 ppm + KNO_3 0.5 % significantly increased the dry matter production, seed yield and harvest index compared to control. This indicates that KNO_3 promoted translocation of assimilates into the reproductive parts and thereby increased the sink size. This was apparent from the data that foliar application of NAA 20 ppm and KNO_3 0.5 % prolonged the seed maturity for 3 days as compared to control which facilitated more assimilate translocation to reproductive parts.

2.2.7.5. GROUNDNUT

Effect of foliar application of a combination of DAP, ammonium sulphate and NAA on groundnut was studied by Pardole and Deshmukh (1982). It was observed that maximum pod yield and net profit can be obtained by this treatment as compared with the full dose of soil applied N and P. A positive response of groundnut to foliar application of boron as boric acid along with NAA was reported by Macwan *et al.* (1991). The foliar application of a combination of urea, phosphorus, trace elements and plant growth regulators to groundnut recorded a yield increase of upto 20 per cent (Balerao *et al.*, 1994).

The response of groundnut to combined nutrient spray of DAP (2.5 kg), ammonium sulphate (1.0 kg), borax (0.5 kg) and NAA (40 ppm) applied at two stages was studied by Subrahmaniyam *et al.* (2000). The results revealed that foliar spraying of nutrient combinations on 25 and 35 DAS which was followed by foliar spray of NAA at 40 ppm alone on 45 and 55 DAS, significantly registered the maximum values of growth and yield attributes. Also a pod yield of 1502 kg ha^{-1} which was 24.6 per cent higher over control was obtained. The foliar application of nutrients and NAA also increased the uptake of nutrients by the crop.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

Field experiments were conducted at Tamil Nadu Agricultural University, Coimbatore, to find out the effect of irrigation layouts and foliar application of different nutrient combinations with growth hormones on the growth, yield and water use efficiency of soybean in *kharif* 1999 and 2000, and *summer* 2000. The materials used and methods adopted for the conduct of the experiments are presented in this chapter.

3.1. Materials

3.1.1. Field Location

The experiments were conducted at the wetlands of Tamil Nadu Agricultural University, Coimbatore. The farm is located in the Western Agro-climatic zone of Tamil Nadu at 11° North latitude and 77° East longitude at an elevation of 426.72 meters above mean sea level.

3.1.2. Season

The experiments were conducted in succession during *kharif,* 1999 (Jul–Oct), *summer,* 2000 (Feb–May) and *kharif,* 2000 (Jul–Oct) under irrigated conditions.

3.1.3. Weather and Climate

The normal weather conditions of the location are as follows: An annual rainfall of 640 mm is distributed over 45 rainy days. The maximum and minimum temperatures are 33.6° and 22.2° C respectively. Relative humidity ranges from 45 to 91 per cent. The bright sunshine hours per day are 7.4 with solar radiation of 400 cal. cm^{-2} day^{-1}. The data on meteorological parameters collected from the Agri-meteorological observatory of Tamil Nadu Agricultural University during the cropping periods are presented in Table 1, 2, 3 and 4 and depicted in Fig. 1, 2 and 3.

3.1.4. Soil Characteristics

The soils of the experimental fields were black clayey in nature, classified taxonomically as Vertic Ustochrefit, with low available N, medium available P and high available K. Mechanical composition of the soil was determined before laying out the experiment as suggested by Piper (1966). The details of soil physical and chemical characteristics are presented in Table 5.

3.1.5. Crop and Variety

Soybean variety CO 1 was used as the test crop. It is a selection from Thailand variety (EC 39821) released for general cultivation. It is a determinate type, erect in growing habit, photo insensitive and resistant to yellow mosaic. It comes to 50 per cent flowering by 37–39 days, and the crop duration is 85-90 days. The seeds of CO 1 soybean is cream coloured and medium sized. It contains 41 per cent protein, 21 per cent oil, 20 per cent carbohydrate, 0.35 per cent calcium and 0.58 per cent phosphorus.

3.1.6. Irrigation Source

The irrigation water was medium in quality with a pH value of 8.1 and medium in anions and cations. The details on the quality of irrigation water are presented in Table 6.

Table 1. Weather data during the cropping period (kharif,99)

Std. Weeks	Months	Temperature °C		Mean R.H (%)	Rainfall (mm)	No. of rainy days	Wind velocity (km hr^{-1})	Pan Evp. (mm day^{-1})	Mean sunshine (hrs. day^{-1})	Solar radiation (cal cm^{-2} day^{-1})
		Max.	Min.							
28	9 July – 15	31.9	22.4	68.0	1.0	0	20.4	6.5	4.6	348.5
29	16 – 22	28.3	22.4	67.0	21.0	4	24.2	4.7	1.2	251.6
30	23 – 29	29.5	23.3	74.0	3.8	1	36.9	7.0	4.1	324.5
31	30 – 5 Aug	30.9	23.2	60.0	0	0	27.6	7.0	5.4	264.9
32	6 – 12	31.2	23.1	68.0	3.0	1	28.0	6.6	4.8	324.6
33	13 – 19	32.7	22.3	68.5	0.2	0	14.8	5.7	8.2	266.2
34	20 – 26	32	21.8	70.0	18.7	1	13.4	4.3	5.6	336.9
35	27 – 2 Sep	32.2	21.9	65.5	0	0	17.6	5.6	7.2	388.1
36	3 – 9	32.3	22.3	60.5	0	0	23.3	7.1	7.9	421.7
37	10 – 16	33	21.4	65.0	0	0	20.3	6.9	9.3	440.0
38	17 – 23	33.7	22.4	69.5	0	0	12.9	5.6	8.0	394.3
39	24 – 30 Oct	33.5	22.9	68.5	28.0	3	8.2	3.7	6.1	351.4
40	1 – 7	29.9	22.5	81.0	72.3	4	6.0	2.8	3.9	282.7
41	8 – 14	30.9	22.3	76.5	31.9	3	3.1	4.2	7.7	386.1
42	15 – 21	29.5	21.9	84.5	155.4	6	2.7	1.9	3.4	282.7

Fig.1 Weather during Cropping period (kharif, 99)

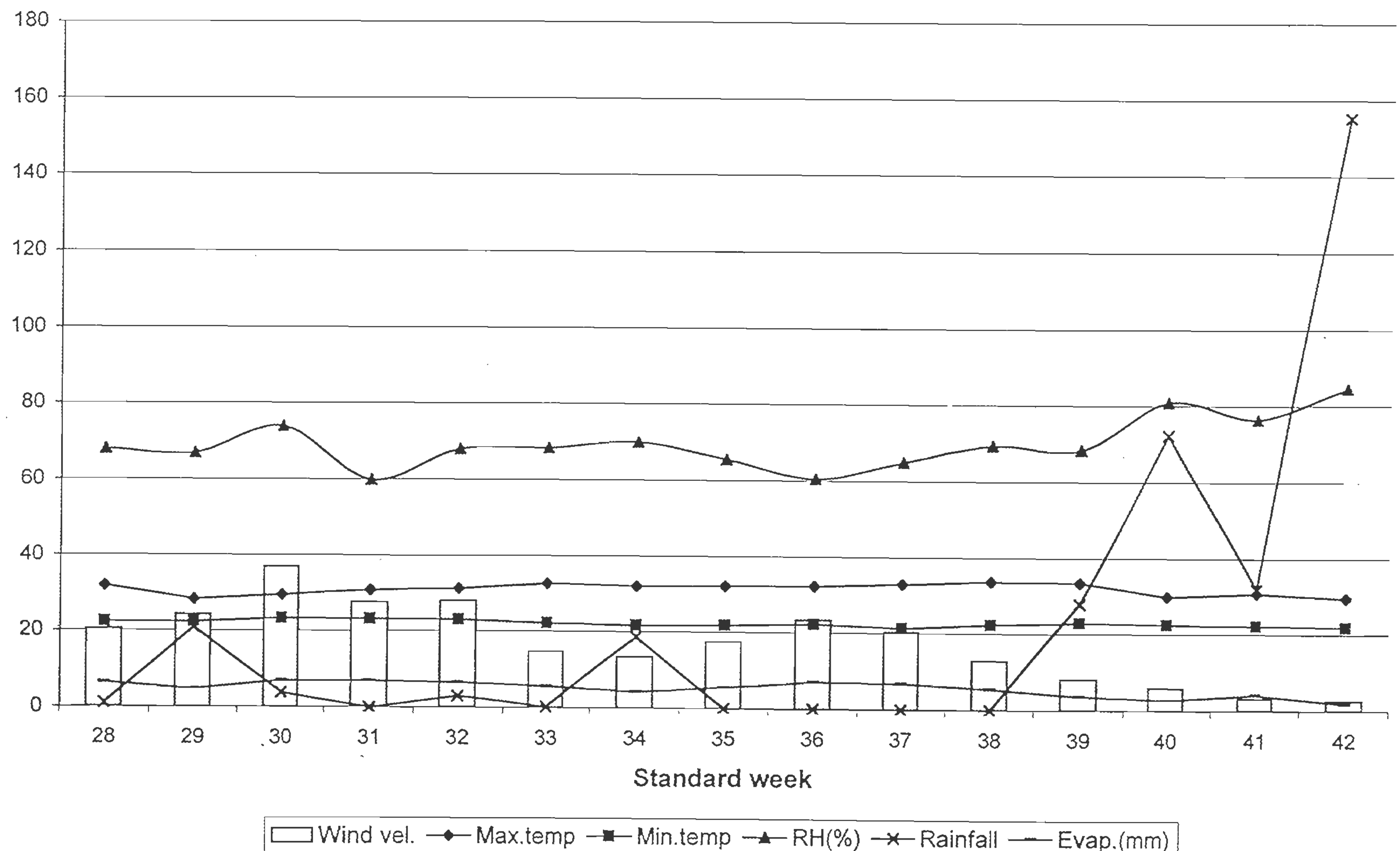


Table 2. Weather data during the cropping period (summer,2000)

Std. Weeks	Months	Temperature °C		Mean R.H (%)	Rainfall (mm)	No. of rainy days	Wind velocity (km hr^{-1})	Pan Evp. (mm day^{-1})	Mean sunshine (hrs. day^{-1})	Solar radiation (cal cm^{-2} day^{-1})
		Max.	Min.							
5	Jan 29-Feb 4	31.0	18.3	64.5	0	0	6.8	4.4	6.7	420.6
6	5-11	32.0	21.9	68.5	0	0	4.4	3.5	7.4	406.6
7	12-18	32.2	18.3	71.5	0	0	5.4	4.9	9.2	425.7
8	19-25	32.7	21.9	67.5	18.0	1	4.5	4.0	5.7	366.2
9	26- Mar 4	30.5	19.9	60.5	18.9	3	4.8	3.6	8.0	383.7
10	5-11	33.9	20.9	59.5	0	0	3.6	4.6	9.4	418.0
11	12-18	35.0	19.6	59.0	0	0	4.6	4.9	9.3	425.7
12	19-25	35.0	19.8	62.5	0	0	6.2	6.4	8.4	451.9
13	26- Apr 1	35.3	21.9	64.0	0	0	6.7	6.8	7.0	391.8
14	2-6	34.6	21.9	65.0	2.5	1	3.5	5.5	8.0	378.5
15	7-15	35.9	22.3	65.0	7.0	1	7.1	6.8	9.5	418.3
16	16-22	34.6	23.1	64.0	10.4	1	5.8	5.9	8.0	382.1
17	23-29	35.5	22.9	62.5	0	0	6.9	5.8	9.6	439.6
18	30- May 6	35.8	20.2	63.0	7.0	2	9.2	7.4	9.8	444.9
19	7-13	35.4	23.7	58.5	6.5	1	6.6	6.1	8.5	412.3

Fig.2 Weather during Cropping period (summer, 2000)

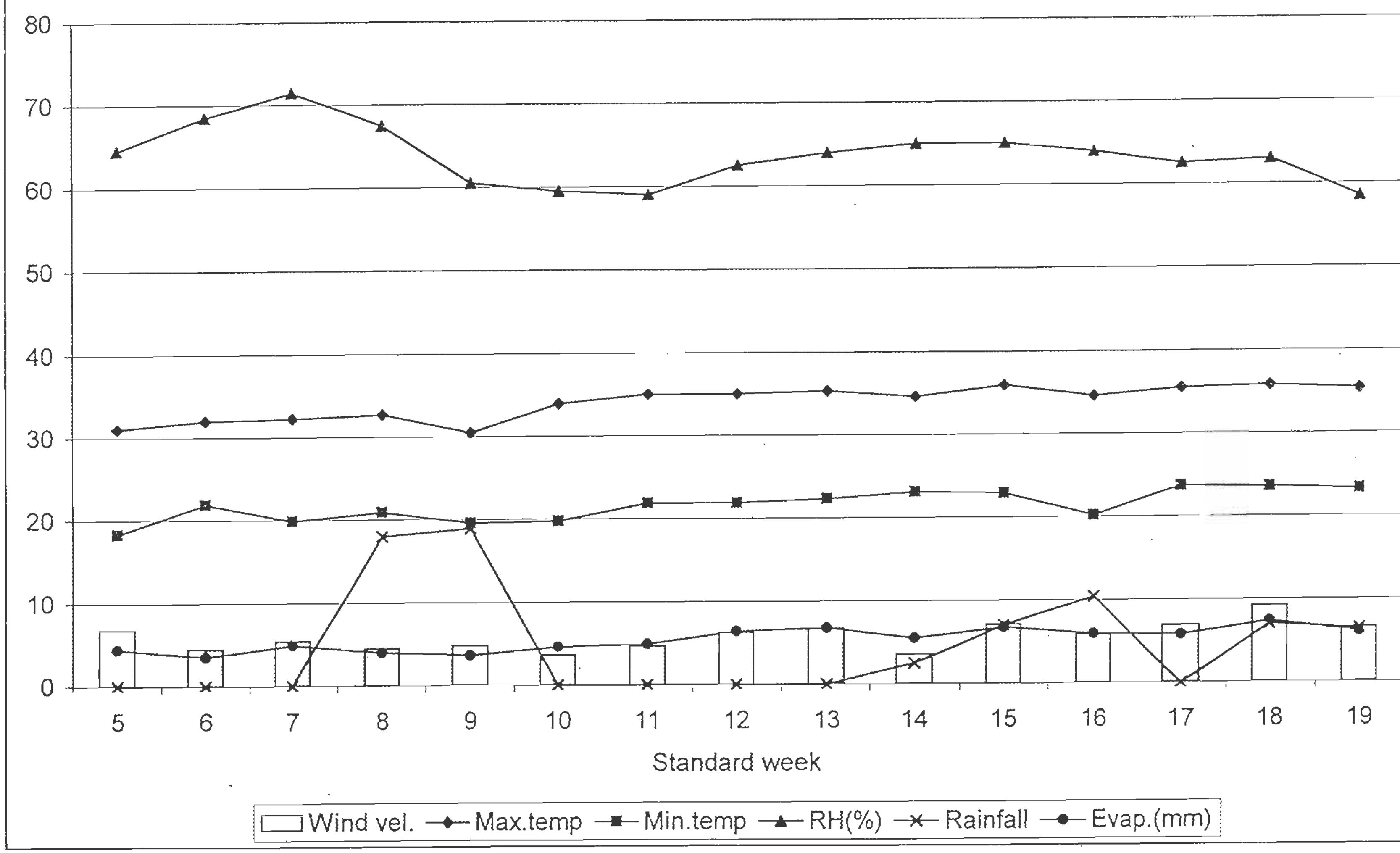


Table 3. Weather data during the cropping period (kharif, 2000)

Std. Weeks	Months	Temperature °C		Mean R.H	Rainfall	No. of rainy days	Wind velocity	Pan Evp.	Mean sunshine	Solar radiation
		Max.	Min.	(%)	(mm)		($km\ hr^{-1}$)	($mm\ day^{-1}$)	($hrs.\ day^{-1}$)	($cal\ cm^{-2}\ day^{-1}$)
26	25- Jul 1	31.5	22.4	63.0	2.3	0	6.6	4.5	16.6	337.9
27	2-8	30.5	22.2	64.5	2.5	1	5.6	2.1	15.4	307.3
28	9-15	30.8	24.2	57.5	12.0	1	10.1	6.1	32.6	380.0
29	16-22	32.2	22.5	62.0	0	0	7.8	7.5	17.6	417.7
30	23-29	32.8	21.9	69.0	0	0	6.3	7.7	7.5	394.1
31	30- Aug 5	32.8	22.6	72.5	41.4	2	5.6	7.8	6.0	380.4
32	6-12	30.2	22.8	65.0	6.2	1	6.5	4.5	21.1	339.5
33	13-19	31.6	22.1	72.0	89.0	1	4.8	5.9	7.2	374.4
34	20-26	28.4	22.8	72.5	22.9	3	4.9	6.8	25.4	255.9
35	27- Sept 2	29.8	21.8	70.0	4.1	1	5.2	6.3	17.0	402.5
36	3-9	32.2	22.1	69.5	0	0	6.8	8.7	9.3	431.3
37	10-16	32.3	22.1	73.5	3.6	1	5.0	6.4	4.9	382.1
38	17-23	31.9	22.5	74.5	89.6	3	3.8	5.2	3.8	328.9
39	24-30	29.6	22.3	81.0	117.2	5	3.2	4.5	3.8	288.2
40	Oct 1-7	29.3	21.4	78.0	10.3	3	4.5	3.5	4.0	303.0
41	8-11	30.9	21.6	75.0	11.3	3	4.1	5.7	3.0	339.0
42	15-21	31.1	21.7	78.0	10.0	1	3.9	4.7	2.5	338.9

Fig.3 Weather during Cropping period (kharif, 2000)

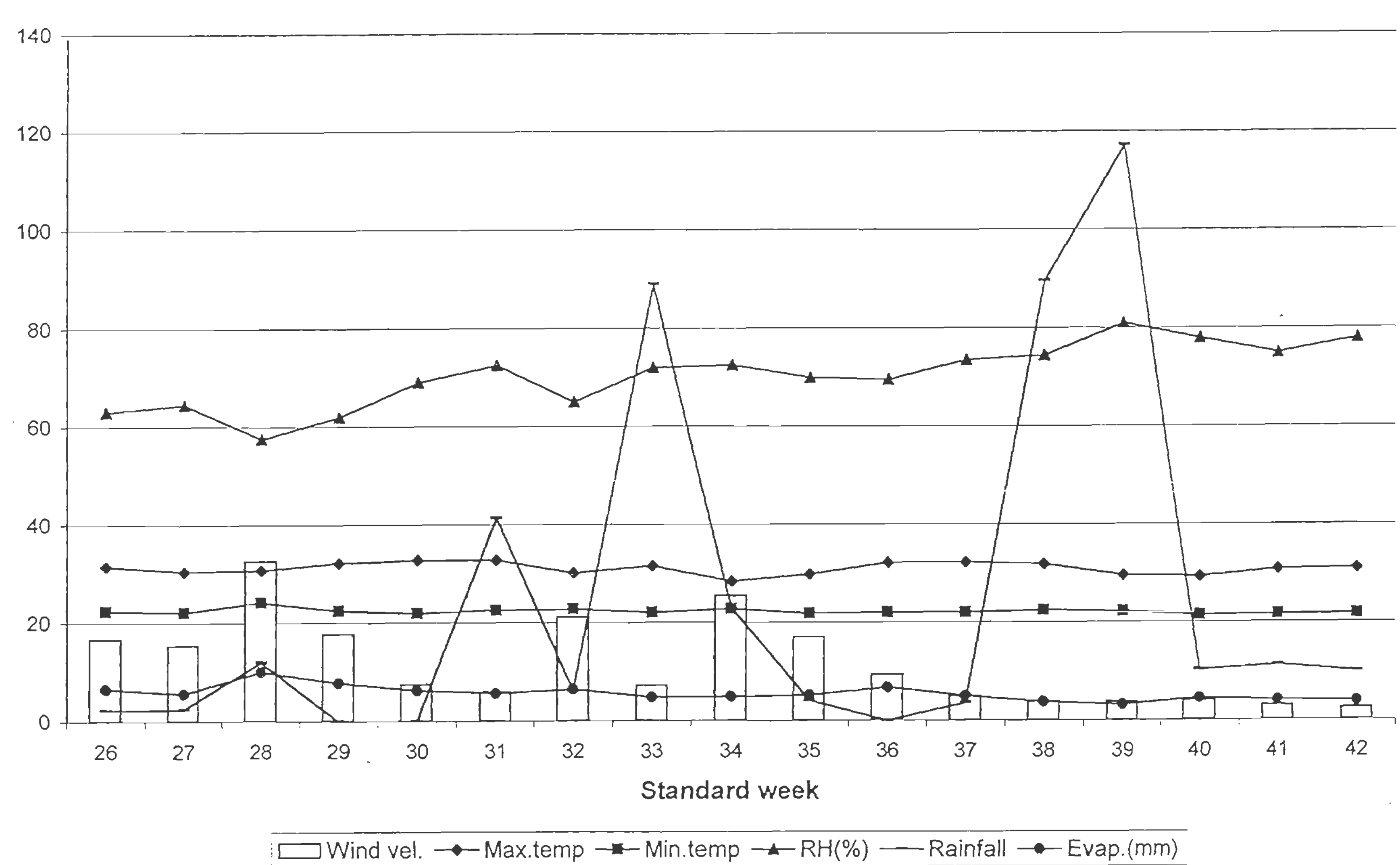


Table 4. Abstract of Observations on Weather parameters

S.No:	Weather parameters	Kharif, 99	Summer, 2000	Kharif, 2000
1.	Total rainfall (mm)	335.3	70.3	422.4
2.	No. of rainy days	23	10	26
3.	Maximum temperature °C			
	Range	28.3 – 33.7	30.5 – 35.9	28.4 – 32.8
	Mean	31.43	33.96	31.05
4.	Minimum temperature °C			
	Range	21.4 – 23.3	18.3 – 23.7	21.4 – 24.2
	Mean	22.46	21.11	22.29
5.	Solar radiation (cal cm^{-2} day^{-1})			
	Range	251.6 – 440	366.2 – 451.9	255.9 – 417.7
	Mean	337.61	411.06	353.0
6.	Sunshine hours (hrs day^{-1})			
	Range	1.2 – 9.3	5.7 – 9.8	2.1 – 8.7
	Mean	5.83	8.30	5.76
7.	Relative humidity (%)			
	Range	60.0 – 84.5	58.5 – 71.5	57.5 – 81.0
	Mean	69.8	63.7	70.44
8.	Pan Evaporation (mm day^{-1})			
	Range	1.9-7.1	3.5-7.4	3.2-10.1
	Mean	5.31	5.37	5.57
9.	Wind velocity (km hr^{-1})			
	Range	2.7-36.9	3.5-9.2	2.5-32.6
	Mean	17.29	5.74	11.63

3.2. Methods

3.2.1. Experimental Design

The experiments were laid out in split plot design and the treatments were replicated three times. Irrigation layouts were in main plots and foliar sprayings of nutrient combinations and NAA were allotted to sub-plots. The treatment details are given below. The field layout plan of the experiments is given in Fig. 4a, 4b and 4c. The different irrigation layouts are also given in Fig. 4d.

A. Main plot treatments

Flat beds	M_1
Flat ridges and furrows	M_2
Ridges and furrows	M_3

B. Subplot treatments

Control (Water spraying)	S_1
DAP 2%	S_2
DAP 2% + KCl 1%	S_3
DAP 2% + KCl 1% + Boron 0.2%	S_4
DAP 2% + KCl 1% + Boron 0.2% + NAA 40 ppm	S_5

3.2.2. Plot size

Gross plot : 5.0 x 4.2 m = 21.00 m^2

Net plot : 4.6 x 3.6 m = 16.56 m^2

Fig. 4a. Layout plan of Experimental field – Kharif' 99

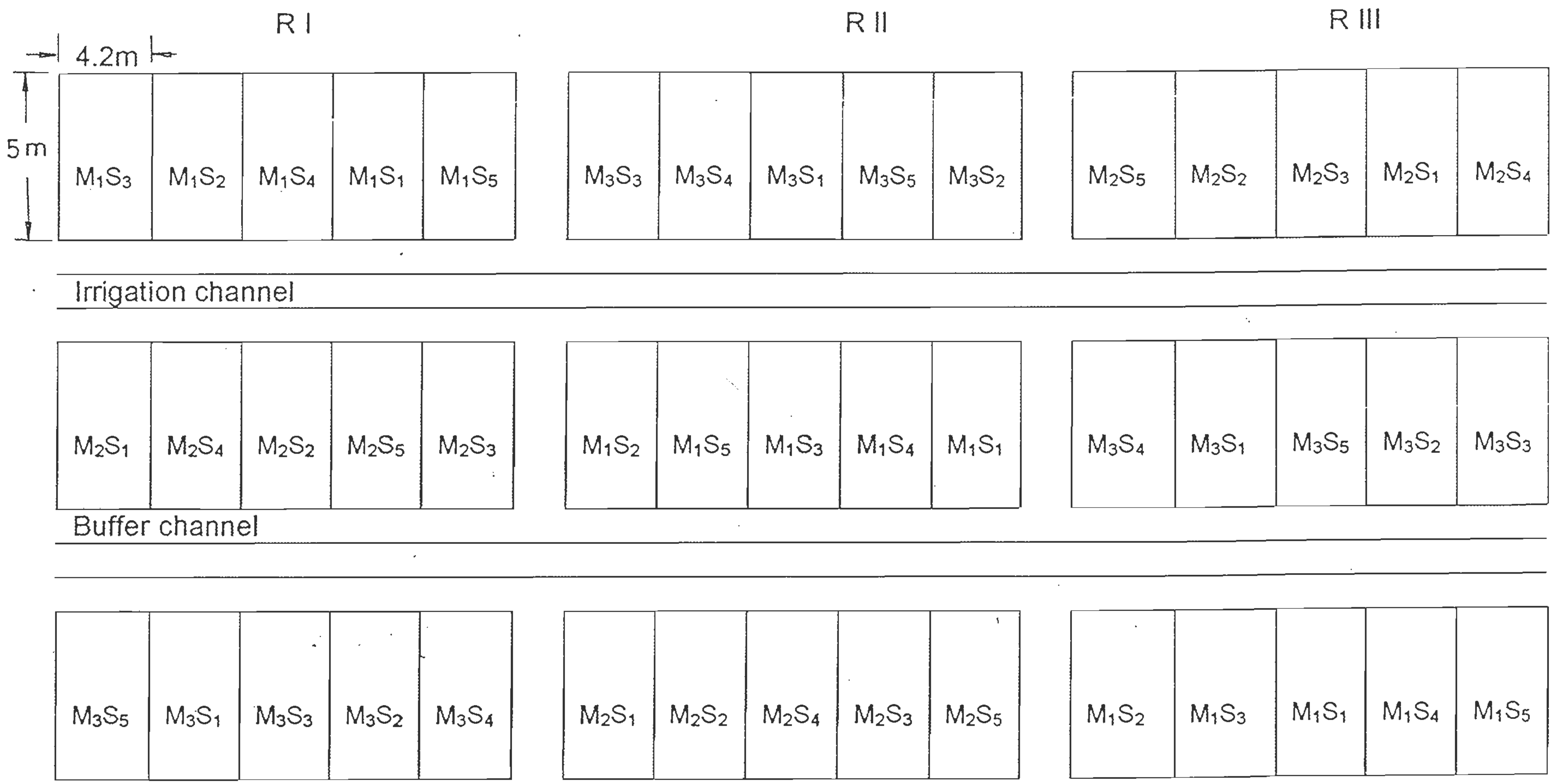


Fig. 4b. Layout plan of Experimental field – Summer 2000

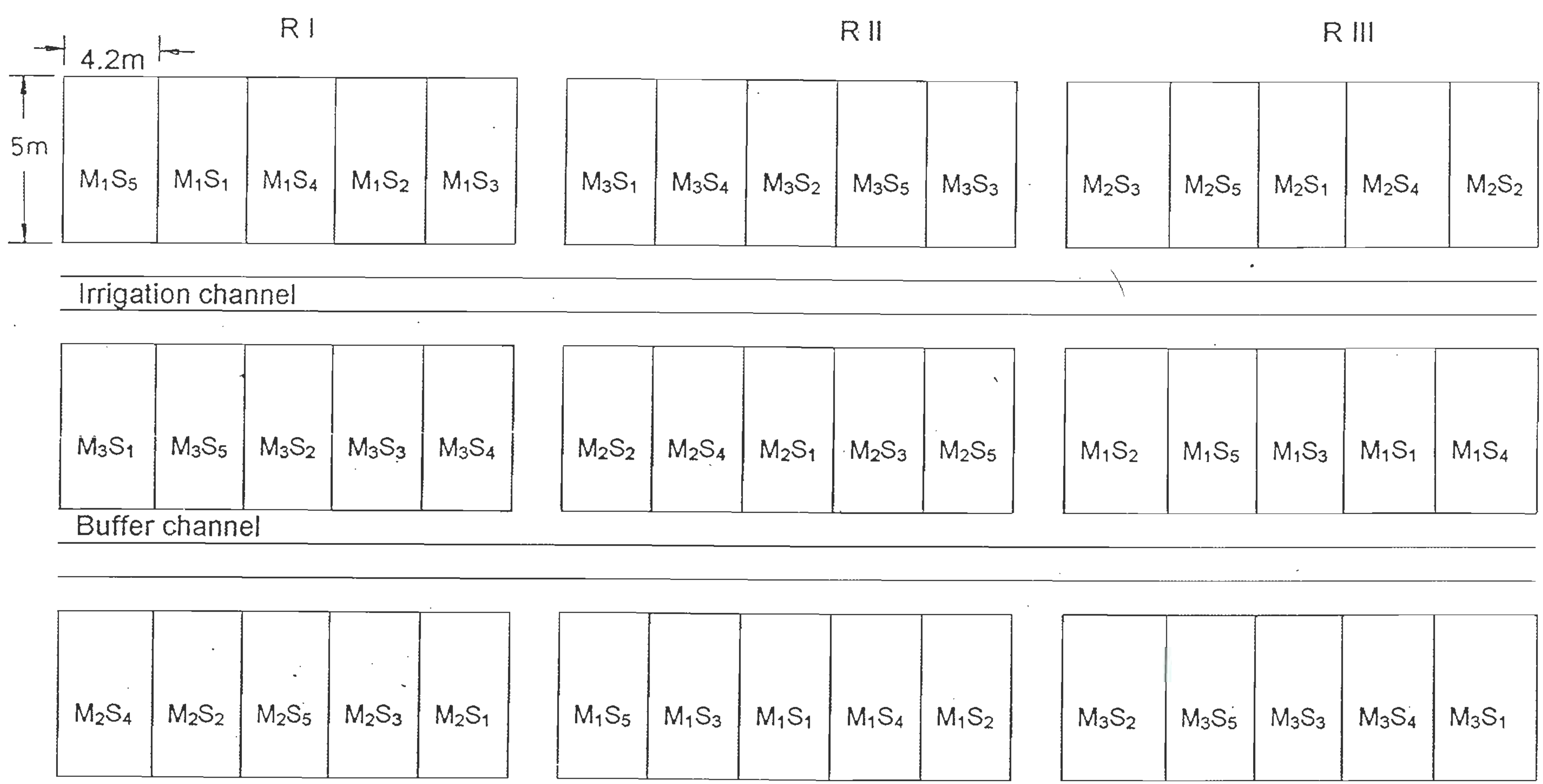


Fig. 4c. Layout plan of Experimental field – Kharif 2000

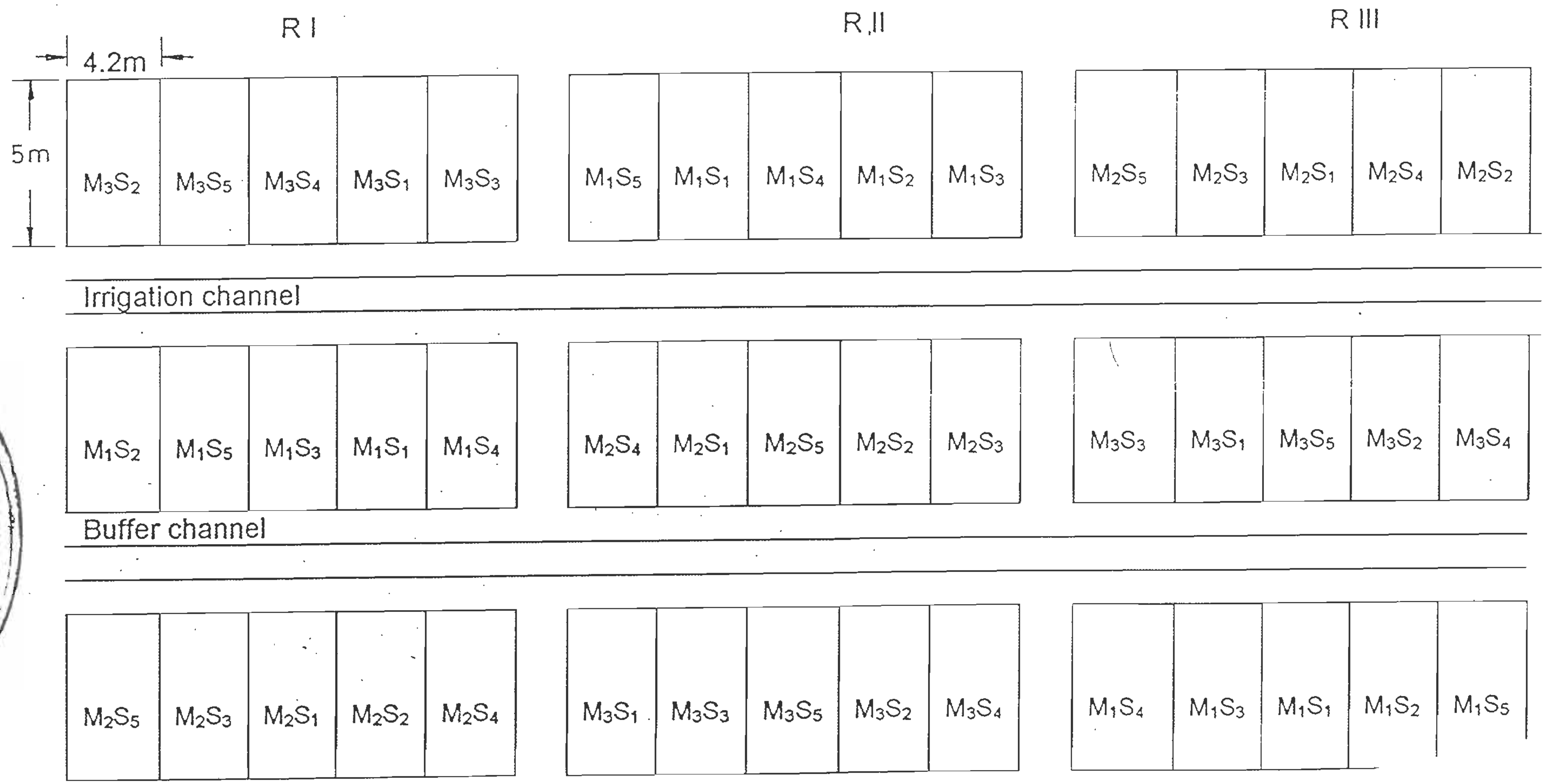
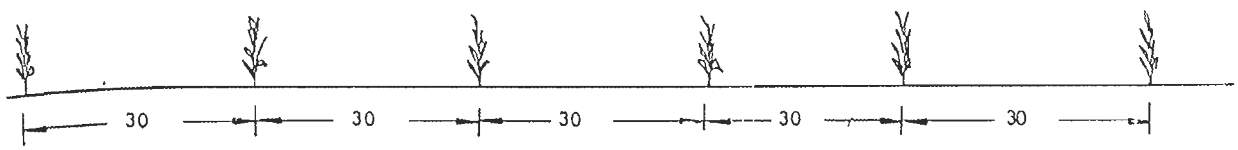


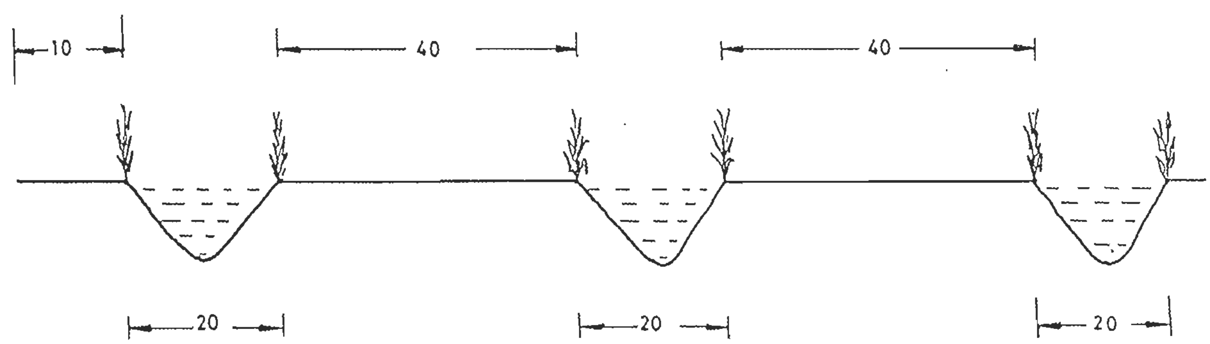
FIG. 4d. LAYOUT PLAN FOR IRRIGATION LAYOUTS

(Dimensions in cm)

FLAT BEDS



FLAT RIDGES AND FURROWS



RIDGES AND FURROWS

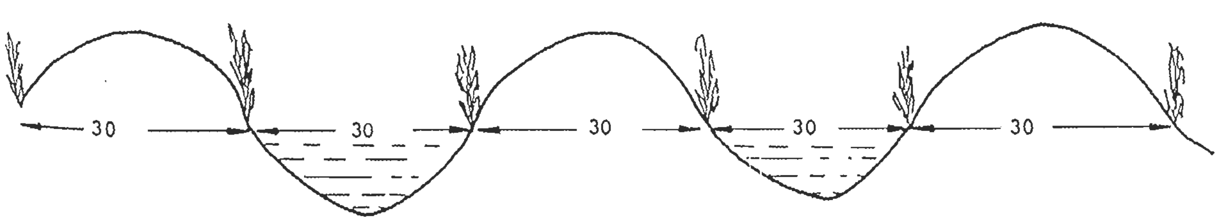


Table 5. Soil Characteristics of the experimental fields

Characteristics	Kharif, 99	Summer, 2000	Kharif, 2000
Mechanical Composition (Piper, 1966)			
Clay (%)	38.4	35.8	33.6
Silt (%)	19.5	22.3	13.8
Coarse sand (%)	25.0	17.5	13.2
Fine sand (%)	17.1	24.4	39.4
Texture	Clay loam	Clay loam	Clay loam
Physical properties (Piper, 1966)			
Field capacity (%)	29.50	29.10	28.90
Permanent wilting point (%)	15.10	15.65	15.93
Bulk density (g cc^{-1})	1.34	1.33	1.30
Total porosity	45.60	47.1	46.3
Particle density (g cc^{-1})	2.18	2.07	2.11
Pore space (%)	39.25	39.75	40.12
Chemical properties			
Electrical conductivity (dsm^{-1})	0.7	0.5	0.6
pH (1:2 Soil water extract)	7.6	7.8	7.9
Nutrient Status			
Available Nitrogen (N kg ha^{-1})	201	235	220
Available Phosphorus (P_2O_5 kg ha^{-1})	12.4	14.7	15.3
Available Potassium (K_2O kg ha^{-1})	478	495	505

Table 6. Quality of irrigation water (Jackson, 1973)

Parameters	Value
Electrical conductivity (dsm^{-1})	0.86
pH	7.7
Anions (ppm)	
Carbonates	Nil
Bicarbonates	4.13
Chlorides	1.64
Sulphates	Traces
Cations (ppm)	
Calcium	0.66
Magnesium	0.43
Sodium	1.10

3.2.3. Crop culture

The experimental fields were prepared by tractor drawn mould board plough followed by harrowing. The fields were perfectly leveled. Flat beds (M_1) were formed with spades to the required size (21 m^2). Flat ridges and furrow (M_2) was formed in flat beds with furrow width of 20 cm. Ridges were formed 60 cm apart and sowing was taken up in both sides of the ridges (M_3). Buffer channels were provided to avoid seepage of water to neighboring plots.

3.2.3.1. Seed treatment

The seeds were treated with carbendazim at the rate of 2g kg^{-1} of seed to control seed borne diseases. The seeds were then treated with the biofertiliser viz., *Bradyrhizobium japonicum* (CO S1) and with *Bacillus megaterium* (Pb 1) using rice gruel as binder.

3.2.3.2. Sowing

Soybean (variety CO 1) seeds were dibbled in lines with the spacing of 30 cm between rows for the treatment M_1 (Flat beds). Under treatment M_2, two rows of seeds were sown along the top edge of the flat ridges formed 20 cm apart and in treatment M_3 two rows of seeds were sown on either side of the ridges formed 60 cm apart. In all the treatments a common spacing of 10 cm was followed between the plants within each row. Thus the recommended population was maintained in all the treatments.

3.2.3.3. Fertiliser application

The recommended dose of nitrogen, at 20 kg ha^{-1} as urea, phosphorus at 80 kg P_2O_5 ha^{-1} as single super phosphate, and potassium at 40 kg K_2O ha^{-1} as muriate of potash were applied as basal to all the plots, at the time of sowing.

3.2.3.4. Foliar application of nutrients and growth hormone

Foliar spraying was given as per treatment schedule 40 DAS and 60 DAS. Di-ammonium phosphate (DAP) at 2 per cent concentration was prepared by dissolving 20 g DAP in one litre of water, keeping it over night and decanting the supernatant solution. One per cent concentration of potassium chloride (KCl) was prepared by dissolving 10 g KCl in one litre of water. Boron 0.2 per cent was prepared by dissolving 2 g borax in one litre of water and 40 ppm Napthalene Acetic Acid (NAA) by dissolving 40 mg NAA in one litre of water. The spraying was given with a low volume sprayer.

3.2.3.5. Herbicide application

Pre-emergence herbicide viz., fluchloralin was applied at 2 lit ha^{-1} on the third day after sowing by using hand operated knap sack sprayer.

3.2.3.6. After cultivation

At the time of sowing, seeds were dibbled in line as solid sowing and thinned to one healthy seedling adopting 10 cm spacing in the line on the 10th day. One hand hoeing and weeding was given at 25 DAS and a weed free condition was maintained in the field.

3.2.3.7. Plant protection

One round of insecticide Endosulfan 35 EC was sprayed 35 DAS at the rate of 2 ml lit^{-1} of water to control the leaf eating caterpillar.

3.2.3.8. Irrigation

Irrigation was given immediately after sowing and life irrigation on the third day to all the plots in the experiment. Subsequent irrigations were given based on climatological approach, at IW/CPE ratio of 0.60. The evaporation was recorded every day from USWB (United States Weather Bureau) class A open pan evaporimeter installed at Agricultural Meteorological observatory of Tamil Nadu Agricultural University.

The M_1 treatment was irrigated to a depth of 50 mm and subsequent irrigations were given when IW/CPE ratio attained 0.60. In M_2 irrigation water was let in narrow channels of 20 cm wide and this consumed 16 mm of water for each irrigation. The treatment M_3 was irrigated in the furrows and the consumption of water was 24 mm for each irrigation. The amount of irrigation water let into each plot was maintained at 3 litres sec^{-1} by using an irrigation module, fixed at the head end of the experimental field.

3.2.3.9. Harvesting and threshing

Harvesting was done when the crop attained maturity by cutting the plants close to the ground. Two border rows at all the sides of the plot were harvested and separated. Thereafter the remaining plants in the net plot were harvested for the purpose of accounting the yield per plot and the yield computed to hectare. The harvested plants were dried and threshed manually. The seeds were separated and cleaned after which they were dried to 12 per cent moisture and the grain yield was recorded. The haulm yield was also recorded after drying the same in the sun. The date of sowing and harvesting of the crops are given below:

Crop	Date of sowing	Date of harvesting	Duration (days)
Kharif' 99	10.7.99	20.10.99	102
Summer 2000	2.2.2000	12.5.2000	100
Kharif 2000	29.6.2000	15.10.2000	110

3.3. Biometric observation

Five plants were selected at random in the net plots for each treatment at different stages as per requirement and the following biometric observations were recorded.

3.3.1. Plant height

Height of the plant was measured from cotyledonary node to the base of the last opened leaf. The height was measured on 30, 60 and 90 DAS and expressed in cm.

3.3.2. Leaf Area Index (LAI)

Leaf area was measured by using leaf area meter (Licor-model 3100). The LAI was computed by dividing the total leaf area with the land area occupied by the plant. The LAI was calculated at 30, 60 and 90 DAS.

3.3.3. Root length

The roots were removed carefully and their mean length from cotyledonary node to the tip of the largest root was measured and expressed in cm.

3.3.4. Number of nodules

Five plants with entire root system were pulled out carefully using a digging fork and the number of nodules in the root was counted at 60 DAS.

3.3.5. Crop Growth Rate (CGR)

The Crop growth rate was calculated from the dry weight of whole plant using the formula suggested by Watson (1956) and expressed in g m^{-2} day^{-1}.

$$CGR = \frac{(W_2 - W_1)}{P\,(t_2 - t_1)}$$

W_1 and W_2 - Whole plant dry weights at t_1 and t_2 respectively

t_1 and t_2 - time interval in days

P - ground area occupied by the plant (cm)

3.3.6. Relative Growth Rate (RGR)

It is the rate of increase in dry weight per unit dry weight in unit time and is expressed in $gg^{-1}day^{-1}$. RGR was calculated as per the formula suggested by Williams (1946).

$$RGR = \frac{\log_e W_2 - \log_e W_1}{(t_2 - t_1)}$$

W_1 and W_2 - Whole plant dry weights at t_1 and t_2 respectively

t_1 and t_2 - time interval in days

3.3.7. Dry matter production (DMP)

Five plants per plot were selected at random and cut close to the ground level and dried in sun and then in hot air oven at 80° C for 72 hours. After this, dry weight of the samples was recorded. The dry weight was recorded at 30, 60 DAS and at harvest and expressed as dry weight per plant.

3.4. Physiological parameters

3.4.1. Relative leaf water content (RLWC)

RLWC of leaves was estimated at 60 DAS as per the method suggested by Weatherly (1950).

$$RLWC = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

3.4.2. Leaf temperature

The leaf temperature was measured in fully expanded young leaf by using LI-1600 auto steady state porometer and expressed in °C and it was recorded at 60 DAS before irrigation.

3.4.3. Stomatal diffusive resistance (SDR)

The SDR was measured at 60 DAS with a pre-calibrated LI-1600 auto steady state porometer. This was measured in a fully expanded young leaf at 12-14 hours and expressed in s cm^{-1}.

3.4.4. Transpiration rate (TR)

The transpiration rate was measured at 60 DAS with a pre-calibrated LI-1600 auto steady state porometer. This was measured in a fully expanded young leaf at 12-14 hours and expressed in µg H_2O cm^{-1} s^{-1}.

3.5. Yield attributes and Yield

3.5.1. Number of pods per plant

The number of pods per plant was recorded from the selected five plants in each treatment at harvest and the average number of pods per plant was recorded.

3.5.2. Number of seeds per pod

The total number of seeds from each pod was recorded for 20 randomly selected pods in each of the five plants selected at random. Similarly the number of filled seeds and unfilled seeds were recorded separately and the filling percentage was as follows

$$\text{Filling percentage} = \frac{\text{Number of filled seeds}}{\text{Total number of seeds}} \times 100$$

3.5.3. Test weight

One hundred seeds were selected at random from each treatment and was weighed and expressed in grams.

3.5.4. Grain and haulm yield

Seed yield was recorded at 12 per cent moisture content from each treatment and computed to hectare expressed in kg ha^{-1}. Haulm yield was recorded after the separation of seeds from plant and expressed in kg ha^{-1}.

3.5.5. Harvest Index (HI)

Five plants were selected at random and their total dry weight excluding root weight and grain yield was recorded. The HI was estimated at maturity and expressed in percentage.

$$HI = \frac{\text{Grain yield}}{\text{Total dry matter}} \times 100$$

3.6. Seed quality

The seed samples were ground using Willey Mill and analysed for protein and oil content.

3.6.1. Protein content

The protein content of seeds was estimated by using near-infra red analyser (Model 102, Pacific Scientific Company, Gardener/Neotac Instrument Division, Maryland). The operating principle of the model 102 is based on infrared spectroscopy.

3.6.2. Oil content

Seed oil content was also estimated along with the protein content using near infra-red analyser and expressed in percentage.

3.7. Chemical analysis

3.7.1. Plant analysis

The plant samples removed for recording dry matter production were ground into fine powder in a Willey mill and used for chemical analysis.

3.7.1.1. Nitrogen uptake (N)

The total N content was estimated by using the microkjeldahl method suggested by Humphries (1956) and expressed in percentage on oven dry basis and computed to kg ha^{-1}.

3.7.2. Phosphorus uptake (P_2O_5)

The total P content was estimated by triacid digestion method described by Jackson (1973) using photo-electric colorimeter and expressed in kg ha^{-1}.

3.7.3. Potassium uptake (K_2O)

The total K content was estimated using triacid digestion method as suggested by Jackson (1973) by using flame photometer and expressed in kg ha^{-1}.

3.8. Soil analysis

Pre-sowing and post-harvest soil samples were collected from the experimental site at random from surface layer (0-15 cm) using screw auger and analysed for physical, chemical and physico-chemical properties. The samples were air dried, sieved through 2 mm sieve before analysis.

3.8.1. Available nitrogen

The available soil nitrogen was examined by the alkaline potassium permanganate method as described by Subbiah and Asija (1956).

3.8.2. Available phosphorus

The available phosphorus was determined by the method as described by Olsen *et al.* (1954).

3.8.3. Available potassium

The available potassium was estimated by using neutral N ammonium acetate extractant and flame photometer as described by Stanford and English (1949).

3.8.4. Organic carbon

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

3.9. Water use components

3.9.1. Total water consumption

The total water consumption in each irrigation treatment was worked out considering the irrigation water applied plus effective rainfall during the crop period.

3.9.2. Water use efficiency (WUE)

The water use efficiency was calculated by using the following formula and expressed in kg ha^{-1} mm^{-1}. Effective rainfall was calculated as suggested by Dastane (1974).

$$WUE = \frac{\text{Seed yield (kg ha}^{-1}\text{)}}{\text{Quantity of irrigation water (mm) + Effective rainfall (mm)}}$$

3.10. Economics

Gross and net returns and benefit-cost ratio were worked out for the different treatments based on cost of cultivation and gross return.

3.12. Statistical analysis

Statistical analysis was carried out based on the procedure given by Gomez and Gomez (1984). Critical difference was worked out wherever the difference was significant at five per cent probability level.

RESULTS

CHAPTER IV

EXPERIMENTAL RESULTS

Field investigations were carried out to find out the influence of irrigation layouts and foliar spraying of nutrients and growth regulators on the growth, yield and water use efficiency of soybean in *kharif* 1999 and 2000 and *summer, 2000.* The results of the experiments are presented in this chapter.

4.1. GROWTH CHARACTERS

4.1.1. Plant height (Tables 7-9)

There was significant influence of irrigation layouts on the plant height on 30 days after sowing (DAS) in *kharif, 2000.* Ridges and furrows (M_3) produced taller plants than the other methods but this method was on par with the flat beds (M_1). Under flat ridges and furrows (M_2), the plants were significantly shorter than the plants under the other two methods. Foliar spraying treatments were not imposed at this stage.

The irrigation layouts also had a significant influence on plant height on 60 DAS in *kharif, 2000.* The plant height was higher under ridges and furrow, closely followed by plants under flat beds (M_1). Shorter plants were observed under the flat ridges and furrows (M_2), but this method was on par with the flat beds (M_1). The irrigation layouts failed to influence the plant height significantly in the other two seasons.

The foliar spraying of different nutrient combinations produced a significant effect on plant height in *kharif, 99* and *summer, 2000.* In *kharif, 99*, foliar spraying of DAP 2%+

Table 7. Effect of irrigation layouts and foliar spraying on plant height (cm) at 30 DAS

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	31.90	29.80	32.33	31.93	32.20	31.63	30.62	27.86	31.99	28.87	29.10	29.68	33.11	33.43	33.78	33.73	33.75	33.36
M_2	34.03	31.30	31.70	30.16	31.97	31.83	34.27	33.33	33.07	32.47	32.30	33.09	30.73	28.61	30.44	30.08	29.49	29.87
M_3	34.17	31.10	34.27	31.67	32.67	32.77	33.97	35.87	35.33	34.27	32.97	34.48	35.05	34.07	33.98	33.26	32.79	33.83
Mean	33.37	30.73	32.77	31.26	32.28		32.95	32.35	33.46	31.87	31.46		32.96	32.04	32.73	32.36	31.68	

	Kharif' 99 SEd	Kharif' 99 CD (P = 0.05)	Summer' 2000 SEd	Summer' 2000 CD (P = 0.05)	Kharif' 2000 SEd	Kharif' 2000 CD (P = 0.05)
M	0.52	NS	1.53	NS	0.94	2.61
S	1.15	NS	1.08	NS	0.72	NS
M at S	1.85	NS	2.27	NS	1.46	NS
S at M	1.98	NS	1.87	NS	1.25	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

Table 8. Effect of irrigation layouts and foliar spraying on plant height (cm) at 60 DAS

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	41.37	46.09	49.76	47.50	45.81	46.10	39.32	41.57	43.73	47.80	44.46	43.37	51.63	45.83	51.67	52.20	51.0	50.47
M_2	42.84	46.02	47.75	44.81	44.91	45.27	41.78	44.76	46.21	47.93	45.12	45.16	46.93	47.03	48.63	50.67	48.10	48.27
M_3	45.82	47.23	48.41	48.62	46.33	47.28	44.26	46.0	48.31	50.47	47.40	47.29	49.60	54.50	50.0	53.23	53.33	52.13
Mean	43.34	46.45	48.64	46.98	45.68		41.79	44.11	46.08	48.74	45.66		49.39	49.12	50.10	52.03	50.81	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	1.72	NS	2.39	NS	0.98	2.72
S	1.13	2.33	0.70	1.45	1.69	NS
M at S	2.45	NS	2.63	NS	2.80	NS
S at M	1.96	NS	1.22	NS	2.93	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

Table 9. Effect of irrigation layouts and foliar spraying on plant height (cm) at 90 DAS

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	69.23	71.53	66.93	67.33	69.33	68.87	67.63	60.95	62.25	63.86	63.21	63.58	71.07	72.03	71.30	73.93	73.50	72.37
M_2	67.27	72.97	67.66	68.93	69.50	69.27	63.26	64.80	68.53	69.87	69.17	67.12	76.47	73.57	74.43	76.23	76.0	75.34
M_3	71.30	66.63	69.50	68.67	73.30	69.88	64.93	66.11	72.39	71.42	72.07	69.38	74.47	73.70	71.80	73.83	71.70	73.10
Mean	69.27	70.38	68.03	68.31	70.71		65.27	63.95	67.72	68.38	68.14		74.0	73.10	72.51	74.67	73.73	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	1.41	NS	0.99	2.77	1.07	NS
S	2.05	NS	1.75	2.42	1.52	NS
M at S	3.48	NS	2.08	NS	2.59	NS
S at M	3.56	NS	2.03	NS	2.63	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

KCl 1% produced taller plants, but this treatment was on par with the combination of DAP 2% + KCl 1% + boron 0.2 % (S_4) and DAP foliar spray (S_2). In *summer, 2000,* spraying of DAP 2% + KCl 1% + boron 0.2 % (S_4) resulted in significantly taller plants. In both the seasons, application of different combinations of nutrients produced significant impact on plant height over the water spraying treatment. However the foliar treatments failed to have significant effect on the plant height at 60 DAS in *kharif,* 2000.

There was significant effect of irrigation layouts and foliar spraying on plant height at 90 DAS in *summer, 2000.* The ridges and furrow produced significantly taller plants than other methods but it was found on par with the flat ridges and furrows. The plants under the flat beds were significantly shorter than the plants under the other layouts. The irrigation layouts however failed to have any significant influence on plant height in *kharif* seasons.

Among the different nutrient spray combinations studied, application of DAP, KCl and Boron (S_4) produced taller plants but it was on par with the combination of DAP, KCl boron and NAA (S_5) and DAP + KCl (S_3). The plant height recorded with DAP and water spraying were significantly lower than the other foliar treatments. The different irrigation layouts and foliar treatments failed to produce any impact on plant height at 90 DAS in both the *kharif* seasons.

From the above results it is summarised that the plant height was significantly higher under the ridges and furrows and the foliar nutrition with DAP, KCl, boron with or without NAA resulted in significantly taller plants. The interaction effect between irrigation layouts and foliar spraying combinations was non-significant. It was also observed that the plant height was lower in *summer* than that of *kharif* seasons. With the advancing age of crop, plant height steadily increased and reached a maximum at 90 DAS.

4.1.2. Leaf Area Index (Tables 10-12)

The leaf area index was influenced significantly by the different irrigation layouts at 30 DAS in *kharif*, 2000. The LAI registered under the flat beds was higher than those under the other methods. This was on par with the flat ridges and furrows method. The LAI recorded under ridges and furrow was lower than the other methods but on par with the flat ridges and furrows. The different irrigation layouts failed to produce significant influence on LAI in *kharif, 99* and *summer, 2000.*

The different irrigation layouts and foliar spraying combinations had no significant influence on LAI at 60 DAS irrespective of the seasons studied. However, lower values of LAI were observed under the control plot receiving water spraying in all the three seasons studied.

Leaf area index recorded at 90 DAS was not significantly influenced under different irrigation layouts in all the three seasons studied. The foliar spraying treatments imparted a significant influence in *kharif*, 99 and *summer*, 2000. Application of DAP, KCl, boron and NAA (S_5) was found superior in its effect on LAI at 90 DAS, but was on par with foliar spraying of DAP + KCl and the combination of DAP, KCl and boron in *kharif*, 99. These treatments were found to be significantly superior over DAP spraying and

Table 10. Effect of irrigation layouts and foliar spraying on Leaf Area Index (LAI) at 30 DAS

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	1.32	1.53	1.27	1.37	1.28	1.35	1.19	1.21	1.23	1.43	1.38	1.29	1.37	1.60	1.64	1.71	1.59	1.58
M_2	1.36	1.22	1.42	1.50	1.44	1.39	1.21	1.12	1.09	1.08	1.19	1.14	1.54	1.38	1.28	1.49	1.59	1.45
M_3	1.69	1.53	1.53	1.43	1.32	1.50	1.14	1.06	1.09	1.23	1.00	1.10	1.36	1.26	1.34	1.32	1.37	1.33
Mean	1.46	1.43	1.41	1.43	1.35		1.18	1.13	1.14	1.25	1.19		1.42	1.41	1.42	1.51	1.52	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P= 0.05)
M	0.09	NS	0.09	NS	0.06	0.17
S	0.09	NS	0.06	NS	0.12	NS
M at S	0.17	NS	0.13	NS	0.21	NS
S at M	0.16	NS	0.11	NS	0.22	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

Table 11. Effect of irrigation layouts and foliar spraying on Leaf Area Index (LAI) at 60 DAS

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	3.36	4.35	4.21	4.25	4.13	4.06	4.20	4.26	4.55	4.43	4.19	4.32	4.12	4.72	4.64	4.44	4.57	4.50
M_2	4.04	4.18	4.26	4.47	4.21	4.23	4.01	4.53	4.44	4.43	4.51	4.38	4.26	4.41	4.44	4.73	4.43	4.45
M_3	4.60	4.28	4.48	4.46	4.35	4.43	4.18	4.38	4.25	4.19	4.07	4.21	4.25	4.19	4.62	4.58	4.40	4.41
Mean	4.00	4.27	4.32	4.39	4.23		4.13	4.39	4.41	4.35	4.26		4.21	4.44	4.57	4.58	4.47	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P= 0.05)
M	0.16	NS	0.15	NS	0.18	NS
S	0.16	NS	0.16	NS	0.13	NS
M at S	0.30	NS	0.29	NS	0.27	NS
S at M	0.27	NS	0.28	NS	0.22	NS

M_1 – Flat beds　　M_2 – Flat ridges and furrows　　M_3 – Ridges and furrows

S_1 – Control　　S_2 – DAP 2 %　　S_3 – S_2 + KCl 1 %　　S_4 – S_3 + Boron 0.2 %　　S_5 – S_4 + NAA 40 ppm

Table 12. Effect of irrigation layouts and foliar spraying on Leaf Area Index (LAI) at 90 DAS

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	3.39	3.85	4.34	4.29	4.64	4.10	2.98	3.39	3.53	3.53	3.39	3.36	4.13	3.93	4.78	4.07	4.38	4.26
M_2	3.63	4.08	4.53	4.21	4.53	4.19	3.09	3.37	3.31	3.41	3.56	3.35	3.89	3.61	3.50	3.49	3.81	3.66
M_3	3.61	3.94	4.23	4.37	4.22	4.07	3.21	3.53	3.29	3.79	3.53	3.47	3.56	3.82	4.05	4.29	3.87	3.92
Mean	3.55	3.96	4.37	4.29	4.46		3.09	3.43	3.38	3.57	3.49		3.86	3.78	4.11	3.95	4.02	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.06	NS	0.16	NS	0.17	NS
S	0.16	0.33	0.13	0.26	0.18	NS
M at S	0.26	NS	0.26	NS	0.33	NS
S at M	0.28	NS	0.22	NS	0.32	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

significantly lowest values of LAI were registered under the control plots. In summer, 2000 the spraying of different nutrient combinations of DAP, KCl or boron with or without NAA was significantly superior over the water sprayed control and on par with each other.

Among the different stages, the LAI values were higher at 60 DAS than the other two stages. The different irrigation layouts and foliar combinations failed to have any significant influence on the LAI. There was no significant interaction effect between the irrigation layouts and foliar spray combinations. Similar trend was observed at all the three stages and seasons studied. In general, the values recorded in *summer* were slightly lower than the *kharif* seasons in all the crop stages.

4.1.3. Root length (cm) (Tables 13-15)

The root length measured at 30 DAS was significantly influenced by varying the irrigation layouts in *kharif,* 99. Ridges and furrow method resulted in significantly higher values of root length, followed by flat ridges and furrows. The root length recorded under flat beds was significantly lower than other two methods.

Both the irrigation layouts and foliar treatments failed to significantly influence the root length at 60 DAS. However foliar application of different combinations of nutrients registered numerically higher values of root length over the control treatment, which received water spraying in all the three seasons.

The root length recorded at 90 DAS varied significantly with respect to irrigation layouts in *kharif,* 99 and *summer,* 2000. Ridges and furrow method produced significantly superior values of root length over the other two methods, followed by flat ridges and

Table 13. Effect of irrigation layouts and foliar spraying on root length (cm) on 30 DAS

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	19.13	18.47	18.71	19.25	17.68	18.65	17.33	16.54	18.99	17.95	17.83	17.73	19.80	17.67	16.41	17.77	17.89	17.91
M_2	20.78	19.96	19.76	19.62	19.04	19.83	20.19	20.55	20.43	20.86	19.94	20.39	16.93	15.52	17.71	15.62	16.52	16.46
M_3	21.25	20.56	20.31	21.19	21.39	20.94	18.17	19.40	18.58	19.64	18.03	18.77	19.21	17.86	18.67	17.81	18.35	18.38
Mean	20.39	19.67	19.59	20.02	19.37		18.57	18.83	19.33	19.48	18.59		18.65	17.02	17.59	17.07	17.59	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.37	1.03	0.85	NS	0.87	NS
S	0.56	NS	0.92	NS	0.72	NS
M at S	0.94	NS	1.66	NS	1.41	NS
S at M	0.97	NS	1.60	NS	1.24	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

Table 14. Effect of irrigation layouts and foliar spraying on root length (cm) on 60 DAS

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	20.50	23.23	23.50	21.47	23.73	22.49	18.43	18.73	20.40	20.03	22.43	20.0	22.77	25.0	25.77	23.40	25.23	24.43
M_2	21.93	25.63	22.57	23.56	24.03	23.55	19.13	24.0	22.97	23.60	23.0	22.54	24.43	23.93	25.0	24.97	23.23	24.31
M_3	20.33	23.53	23.60	22.80	23.97	22.85	18.53	23.67	21.60	21.10	22.63	21.51	21.33	22.97	26.33	24.77	23.63	23.81
Mean	20.92	24.13	23.22	22.61	23.91		18.70	22.13	21.65	21.58	22.69		22.84	23.97	25.70	24.38	24.03	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.94	NS	1.24	NS	0.50	NS
S	1.14	NS	1.34	NS	1.08	NS
M at S	2.00	NS	2.41	NS	1.75	NS
S at M	1.97	NS	2.32	NS	1.87	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

Table 15. Effect of irrigation layouts and foliar spraying on root length (cm) on 90 DAS

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	23.33	22.53	24.87	24.47	26.03	24.25	20.07	22.63	24.53	25.60	25.20	23.61	23.07	24.97	23.83	25.63	24.97	24.49
M_2	26.17	26.67	29.0	28.83	27.8	27.69	27.0	26.8	26.50	26.53	25.83	26.54	27.7	27.87	28.5	29.47	28.57	27.13
M_3	28.53	29.83	27.90	32.07	30.53	29.77	27.83	29.63	30.17	30.47	31.07	29.83	27.13	31.2	29.87	30.33	31.40	29.99
Mean	28.01	26.34	27.26	28.46	28.12		24.97	26.36	27.08	27.53	27.37		25.97	28.01	27.40	28.48	28.31	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.59	1.65	1.42	3.95	2.08	NS
S	1.12	NS	1.03	NS	1.18	NS
M at S	1.84	NS	2.13	NS	2.76	NS
S at M	1.94	NS	1.77	NS	2.04	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % $S_3 – S_2$ + KCl 1 % $S_4 – S_3$ + Boron 0.2 % $S_5 – S_4$ + NAA 40 ppm furrows in *summer*. These two methods were on par with each other in *kharif*, 99. The flat beds registered lowest values of root length in both the seasons.

The different spray combinations failed to influence the root length at 90 DAS in all the three seasons studied. The root length progressively increased with the advancing age of the crop. The ridges and furrow method recorded the highest values of root length. The foliar spraying treatments did not produce any significant effect on root length at all stages of crop growth and in all the three seasons studied. Root length measured in the *summer* season was slightly lower than in the *kharif* seasons.

4.1.4. Number of nodules (Tables 16)

The different irrigation layouts influenced the number of nodules per plant significantly in the *summer* season. Ridges and furrows method resulted in higher number of nodules as compared to the other layouts. This method was on par with the flat ridges and furrows. The flat bed method however registered significantly lower number of nodules.

The different combinations of nutrient spray failed to have any influence on the nodule number irrespective of the season. The nodule count recorded in *summer* was found to be lower than the *kharif* seasons.

4.1.5. Crop Growth Rate (g m^{-2} day^{-1}) (30-60 DAS) (Table 17,18)

The crop growth rate (CGR) during 30-60 DAS was influenced significantly by the different irrigation layouts in *summer,* 2000. Ridges and furrow method resulted in

Table 16. Effect of irrigation layouts and foliar spraying on number of effective nodules per plant (60 DAS)

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	18.03	19.93	19.13	18.37	18.47	18.79	16.80	16.53	17.30	18.27	17.80	17.34	19.47	17.93	20.80	19.13	19.67	19.40
M_2	18.23	18.80	18.30	18.23	18.10	18.87	20.67	20.23	19.20	19.97	19.13	19.84	18.0	18.73	19.80	16.90	18.03	18.29
M_3	18.87	19.10	18.97	18.23	19.13	18.86	21.43	19.90	19.53	19.33	21.03	21.25	17.83	18.93	19.67	19.73	18.47	18.93
Mean	18.38	19.28	18.80	18.28	18.57		19.63	18.89	18.68	19.19	19.32		18.43	18.53	20.09	18.59	18.72	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.59	NS	0.38	1.07	0.94	NS
S	0.83	NS	0.65	NS	0.65	NS
M at S	1.41	NS	1.08	NS	1.38	NS
S at M	1.43	NS	1.13	NS	1.13	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

Table 17. Effect of irrigation layouts and foliar spraying on crop growth rate (CGR) ($gm^{-2}\ day^{-1}$) (30 – 60 DAS)

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	7.93	7.68	7.89	8.03	7.41	7.79	6.71	7.91	7.22	7.71	7.80	7.47	8.45	9.36	8.35	9.26	8.56	8.79
M_2	7.87	7.76	7.62	8.01	8.10	7.87	7.48	7.88	7.56	8.37	7.61	7.78	8.89	8.60	8.06	8.92	8.74	8.64
M_3	7.87	8.04	8.17	7.96	7.86	7.98	8.44	7.92	8.34	8.13	8.45	8.26	8.43	8.99	8.90	8.85	8.86	8.81
Mean	7.89	7.83	7.89	7.99	7.79		7.55	7.90	7.71	8.07	7.95		8.59	8.98	8.44	9.01	8.72	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.10	NS	0.13	0.37	0.10	NS
S	0.28	NS	0.25	NS	0.22	NS
M at S	0.45	NS	0.41	NS	0.35	NS
S at M	0.49	NS	0.43	NS	0.38	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

Table 18. Effect of irrigation layouts and foliar spraying on crop growth rate (CGR) ($gm^{-2} day^{-1}$) (60 – 90 DAS)

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	5.11	5.33	5.55	5.33	5.34	5.33	4.45	4.95	4.86	4.85	4.82	4.79	4.92	5.49	5.23	5.41	5.24	5.26
M_2	5.39	5.21	5.57	5.34	5.23	5.35	4.98	5.39	5.45	5.28	5.10	5.24	5.06	5.41	5.47	5.51	5.39	5.37
M_3	5.41	5.48	5.46	5.18	5.21	5.35	4.98	5.38	5.58	5.83	5.65	5.48	4.97	5.44	5.53	5.39	5.28	5.32
Mean	5.30	5.34	5.52	5.28	5.26		4.80	5.24	5.29	5.32	5.19		4.98	5.45	5.41	5.44	5.30	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.08	NS	0.06	0.17	0.04	NS
S	0.14	NS	0.10	0.20	0.11	0.23
M at S	0.24	NS	0.16	NS	0.18	NS
S at M	0.25	NS	0.17	NS	0.19	NS

M_1 – Flat beds · M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % $S_3 - S_2$ + KCl 1 % $S_4 - S_3$ + Boron 0.2 % $S_5 - S_4$ + NAA 40 ppm

significant increase in CGR over the other layouts. The CGR recorded under flat ridges and furrows and flat beds were significantly lower than ridges and furrows but on par with each other. The irrigation layouts failed to impart any influence on CGR in the *kharif* seasons. The different nutrient combinations failed to influence the CGR but the values were in general higher over water spraying treatment.

The CGR coinciding with the period between 60-90 DAS was influenced by the different irrigation layouts in *summer*, 2000. The flat ridges and furrows resulted in significantly higher values of CGR followed by the values under ridges and furrows. The flat beds registered significantly lower values of CGR. The spraying of different nutrient combinations produced significant influence on CGR in summer and *kharif* seasons of 2000. Spraying of different combinations of nutrients viz., DAP, KCl and boron with or without NAA had significantly superior effect over water spraying treatment and were on par with each other.

The CGR recorded in *summer* season was slightly lower than during *kharif* seasons. The interaction effect between irrigation layouts and foliar sprayings was found to be non-significant.

4.1.6. Relative Growth Rate (g g^{-1} day^{-1} $x10^{-2}$) (30-60 DAS) (Table 19, 20)

The different irrigation layouts affected the relative growth rate (RGR) of soybean in both the *kharif* seasons. Ridges and furrow method registered significantly highest values and the flat beds significantly lowest values of RGR in *kharif*, 99. However in *kharif*, 2000 flat ridges and furrows registered higher values of RGR and was found to be

Table 19. Effect of irrigation layouts and foliar spraying on relative growth rate (RGR) (gg^{-1} day^{-1} x 10^{-2}) (30 – 60 DAS)

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	2.54	2.31	2.83	2.67	2.42	2.55	2.59	2.47	3.01	2.69	2.61	2.67	2.77	2.63	3.15	2.96	2.76	2.85
M_2	2.90	2.89	2.52	3.07	3.03	2.88	3.11	2.93	2.81	3.15	3.08	3.02	3.01	3.13	2.95	3.09	3.19	3.07
M_3	2.80	3.22	3.08	2.74	3.28	3.02	2.89	3.13	3.02	2.89	3.16	3.02	3.07	3.17	2.95	2.81	2.86	2.97
Mean	2.75	2.80	2.81	2.82	2.91		2.86	2.85	2.95	2.92	2.95		2.95	2.98	3.02	2.95	2.94	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.04	0.12	0.06	NS	0.05	0.13
S	0.04	0.09	0.04	NS	0.06	NS
M at S	0.08	NS	0.09	NS	0.10	NS
S at M	0.07	NS	0.07	NS	0.10	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

Table 20. Effect of irrigation layouts and foliar spraying on relative growth rate (RGR) (gg^{-1} day^{-1} x 10^{-2}) (60 – 90 DAS)

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	0.593	0.620	0.647	0.683	0.707	0.650	0.560	0.580	0.610	0.643	0.651	0.609	0.610	0.627	0.650	0.673	0.690	0.650
M_2	0.603	0.623	0.606	0.690	0.663	0.649	0.577	0.627	0.613	0.623	0.610	0.610	0.610	0.640	0.677	0.693	0.640	0.652
M_3	0.597	0.620	0.650	0.700	0.720	0.657	0.560	0.590	0.613	0.630	0.633	0.605	0.627	0.623	0.667	0.690	0.667	0.655
Mean	0.600	0.620	0.650	0.690	0.700		0.566	0.599	0.612	0.632	0.631		0.616	0.630	0.664	0.686	0.666	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.007	NS	0.011	NS	0.008	NS
S	0.010	0.020	0.009	0.020	0.011	0.023
M at S	0.017	NS	0.019	NS	0.019	NS
S at M	0.018	NS	0.017	NS	0.019	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

on par with ridges and furrows. The RGR recorded under flat beds was lower than other layouts but on par with ridges and furrows.

The different foliar spray treatments significantly influenced the RGR only in *kharif*, 99. The combined application of DAP, KCl, boron and NAA (S_5) registered higher values of RGR as against other treatments but this was on par with the combination of DAP, KCl and boron (S_4). The RGR under different spray combinations were however on par with the water spraying treatment which registered lower values.

The RGR corresponding to the period 60-90 DAS was not significantly influenced by the different irrigation layouts irrespective of the seasons studied. Among the different combinations of foliar sprays compared, application of DAP, KCl, boron and NAA (S_5) was found significantly superior over the rest of the treatments but on par with the combination of DAP, KCl and boron (S_4) in *kharif*, 99. In *summer* and *kharif*, 2000, the RGR values recorded with these two treatments were found to be on par with spray combination of DAP + KCl (S_3). Lower values of RGR were observed in the control treatment receiving water spray. The RGR values corresponding to the period between 30-60 DAS registered in *summer* were slightly lower than the rates recorded in *kharif* seasons. Such seasonal effect was not observed during the period 60-90 DAS. The interaction effect between the irrigation layouts and foliar spray combinations was found non-significant.

4.1.7. Total dry weight per plant (g) (Tables 21 - 23)

The total dry weight per plant measured at 30 DAS was influenced significantly by different irrigation layouts in *kharif* and *summer* seasons of 2000. Ridges and furrow

Table 21. Effect of irrigation layouts and foliar spraying on total dry weight per plant (g) at 30 DAS

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	2.55	2.24	2.38	2.67	2.23	2.42	2.55	2.47	2.41	2.55	2.53	2.50	3.13	3.45	3.18	3.30	3.31	3.27
M_2	2.33	2.66	2.33	2.15	2.34	2.36	2.85	2.88	2.74	2.82	2.83	2.83	2.85	2.65	2.77	2.68	2.59	2.71
M_3	2.69	2.69	2.62	2.44	2.66	2.58	2.59	2.70	2.69	2.67	2.68	2.69	3.80	3.83	3.67	3.72	3.77	3.56
Mean	2.53	2.51	2.38	2.49	2.38		2.70	2.68	2.61	2.68	2.68		3.26	3.31	3.21	3.24	3.22	

	SEd	CD (P = 0.05)	SEd	CD (P= 0.05)	SEd	CD (P = 0.05)
M	0.07	0.19	0.02	0.05	0.12	NS
S	0.07	NS	0.05	NS	0.13	NS
M at S	0.13	NS	0.09	NS	0.24	NS
S at M	0.12	NS	0.09	NS	0.23	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

Table 22. Effect of irrigation layouts and foliar spraying on total dry weight per plant (g) at 60 DAS

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	11.82	13.11	12.69	14.57	13.55	13.15	10.20	11.56	11.73	12.05	12.12	11.53	10.33	10.43	11.02	10.82	11.31	10.78
M_2	10.57	11.61	11.33	12.70	12.07	11.65	12.50	12.83	13.31	12.94	13.38	12.99	10.66	11.23	11.64	11.45	11.55	11.31
M_3	12.65	13.72	13.11	12.57	12.37	12.88	11.52	12.77	12.23	12.68	12.87	12.41	10.63	11.37	12.37	11.76	12.09	11.64
Mean	11.68	12.81	12.37	13.28	12.66		11.41	12.38	12.42	12.55	12.79		10.54	11.01	11.68	11.34	11.65	

	Kharif' 99 SEd	Kharif' 99 CD (P = 0.05)	Summer' 2000 SEd	Summer' 2000 CD (P = 0.05)	Kharif' 2000 SEd	Kharif' 2000 CD (P = 0.05)
M	0.22	0.62	0.33	0.93	0.38	NS
S	0.24	0.50	0.23	0.47	0.38	0.78
M at S	0.43	NS	0.48	NS	0.70	NS
S at M	0.42	NS	0.39	NS	0.65	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

Table 23. Effect of irrigation layouts and foliar spraying on total dry weight per plant (g) at 90 DAS

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	18.20	19.79	20.47	19.95	19.97	19.67	18.64	21.50	20.44	21.78	22.05	20.88	18.66	20.56	19.58	21.16	20.45	20.08
M_2	18.89	19.14	19.65	20.04	19.24	19.39	23.01	24.75	23.73	24.19	24.28	23.99	19.60	19.84	20.42	20.24	20.58	20.13
M_3	18.97	20.54	20.22	19.73	20.36	19.96	21.79	22.76	22.04	23.63	24.09	22.86	19.65	19.27	20.18	19.74	19.69	19.71
Mean	18.69	19.82	20.11	19.90	19.86		21.15	23.00	22.07	23.20	23.48		19.31	19.89	20.06	20.38	20.24	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.87	NS	0.72	1.99	0.32	NS
S	0.81	NS	0.28	0.58	0.88	NS
M at S	1.53	NS	0.84	NS	1.41	NS
S at M	1.40	NS	0.49	NS	1.53	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

method resulted in significantly higher total plant dry weight over the other layouts in *kharif,* 2000 and the flat ridges and furrows registered significantly higher dry weights in the *summer,* 2000.

The irrigation layouts had significant effect on plant dry weights at 60 DAS in *kharif,* 99 and *summer,* 2000. The values measured under ridges and furrows were superior over other methods, but this method was on par with the flat beds and significantly lower values were recorded under flat ridges and furrows in *kharif,* 99. In *summer* season the total dry weight under flat ridges and furrows were on par with the ridges and furrows.

Foliar spraying of different combination of nutrients affected the plant dry weight recorded at 60 DAS. All the nutrient combinations imparted significant positive influence on plant dry weight over the water spraying treatment and were on par with each other. Similar trend on plant dry weight by different treatments was observed in all the three seasons. The interaction effect between irrigation layouts and foliar sprays was found to be non-significant.

The influence of irrigation layouts and foliar treatments on dry weight of plants was significant at 90 DAS only in the *summer* season. Flat ridges and furrows registered higher total dry weight and was on par with the ridges and furrows. The flat beds registered lower values of dry weight. Such significant influence of irrigation layouts or foliar sprays on plant dry weight was not observed in the *kharif* seasons.

Among the spray combinations, foliar application of DAP, KCl, boron and NAA (S_5) registered higher values of dry weight which was on par with the combination of

DAP, KCl and boron (S_4) and DAP spray (S_2). The plant total dry weight, under the nutrient combinations were found to be significantly superior to water spraying treatment.

In general ridges and furrow method was found superior to other layouts with regard to its effect on plant dry weight. All the nutrient combinations were significantly superior over the water spraying treatment. The seasonal influence on the plant dry weight was not observed at any of the growth stages. The interaction between the irrigation layouts and foliar spraying treatments were found to be non-significant.

4.2. PHYSIOLOGICAL PARAMETERS

4.2.1. Relative leaf water content (Table 24)

The different irrigation layouts had significant effect on the relative leaf water content in *summer* and *kharif* seasons of 2000. Among the different layouts, ridges and furrow method recorded maximum values of relative leaf water content, which was on par with those under flat beds in the *summer* season and with flat ridges and furrows in *kharif, 2000*. The effect of irrigation layouts on leaf water content was not observed in *kharif, 99*.

The foliar spray combinations significantly influenced the leaf water content in all the three seasons studied. Among the different foliar spray combinations, application of DAP, KCl, boron (S_4) recorded higher values of relative leaf water content which was on par with this treatment inclusive of NAA (S_5) and the combination of DAP + KCl (S_3). The DAP spray and control treatments however registered lower values of leaf water content.

Table 24. Effect of irrigation layouts and foliar spraying on relative leaf water content

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	81.37	80.91	82.80	82.50	82.18	81.95	80.49	81.12	84.71	83.78	83.48	82.71	81.39	82.99	83.75	83.61	83.31	83.01
M_2	81.53	81.82	82.49	82.72	82.91	82.29	80.12	80.93	82.87	83.62	82.46	81.99	82.63	83.35	83.74	84.09	84.18	83.60
M_3	81.13	81.26	82.82	83.03	82.70	82.19	80.89	82.55	83.78	84.05	83.67	82.99	83.90	84.18	84.23	84.29	84.31	84.18
Mean	81.34	81.33	82.70	82.75	82.59		80.50	81.53	83.78	83.81	83.20		82.64	83.51	83.91	83.99	83.93	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.31	NS	0.14	0.39	0.19	0.54
S	0.17	0.34	0.34	0.71	0.33	0.68
M at S	0.40	NS	0.55	NS	0.55	NS
S at M	0.29	NS	0.60	NS	0.57	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

The interaction effect of irrigation layouts and foliar spray was not significant in all the three seasons. Lower values of relative leaf water content were recorded in *summer* than *kharif* seasons.

4.2.2. Leaf temperature (°C) (Table 25)

The different irrigation layouts had a significant impact on leaf temperature. Ridges and furrows system recorded significantly lowest values of leaf temperature in both the *kharif* seasons studied. In *summer* it was on par with leaf temperature under flat ridges and furrows. Highest leaf temperature was recorded under flat beds under all the seasons studied. However it was on par with the leaf temperature recorded under flat ridges and furrows.

Among the different foliar spray treatments, combinations including KCl (S_5, S_4 and S_3) registered lowest values of leaf temperature and were on par with each other. Foliar spraying of DAP (S_2) recorded slightly lower values of leaf temperature and it was on par with water spraying in the *kharif* seasons, but significantly different from water spraying in *summer*. The interaction effect of irrigation and foliar spray was not significant in all the three seasons. The values of leaf temperature were slightly higher in *summer* than in *kharif* seasons.

4.2.3. Stomatal diffusive resistance (s cm $^{-1}$) (Table 26)

The stomatal diffusive resistance was significantly influenced by irrigation layouts in *kharif, 99* and in the other two seasons the layouts had no significant impact on stomatal

Table 25. Effect of irrigation layouts and foliar spraying on leaf temperature (°C)

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	34.47	34.50	33.77	33.90	33.77	34.08	37.52	36.60	35.68	35.81	35.94	36.31	34.73	34.67	33.90	33.93	33.93	34.23
M_2	34.50	34.40	33.63	33.77	33.70	34.00	36.62	36.29	36.06	35.99	35.90	36.17	34.73	34.77	33.93	33.63	33.70	34.15
M_3	33.87	33.87	33.47	33.50	33.70	33.68	36.35	35.97	35.79	35.68	35.66	35.89	33.83	34.03	33.53	33.37	33.43	33.64
Mean	34.28	34.26	33.62	33.72	33.72		36.83	36.29	35.84	35.82	35.83		34.43	34.48	33.78	33.64	33.68	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.08	0.22	0.12	0.32	0.07	0.19
S	0.14	0.28	0.15	0.32	0.14	0.29
M at S	0.22	NS	0.28	NS	0.23	NS
S at M	0.24	NS	0.29	NS	0.25	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

Table 26. Effect of irrigation layouts and foliar spraying on stomatal diffusive resistance (SDR)

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	1.52	1.52	1.65	1.66	1.67	1.61	1.53	1.52	1.58	1.57	1.55	1.55	1.48	1.56	1.47	1.43	1.42	1.47
M_2	1.48	1.52	1.57	1.58	1.59	1.55	1.49	1.55	1.54	1.52	1.53	1.53	1.54	1.41	1.50	1.46	1.45	1.47
M_3	1.38	1.34	1.57	1.50	1.51	1.46	1.51	1.54	1.59	1.55	1.56	1.55	1.41	1.47	1.60	1.55	1.59	1.52
Mean	1.45	1.46	1.60	1.58	1.59		1.51	1.54	1.57	1.55	1.55		1.47	1.48	1.52	1.48	1.49	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.03	0.07	0.01	NS	0.05	NS
S	0.02	0.05	0.01	0.03	0.06	NS
M at S	0.05	NS	0.03	NS	0.11	NS
S at M	0.04	NS	0.02	NS	0.10	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

diffusive resistance. Ridges and furrows registered lowest values of diffusive resistance and higher resistance was measured under flat beds.

The nutrient spray combinations influenced the diffusive resistance in *kharif,* 99 and *summer,* 2000. The foliar spray combinations including KCl registered higher values of resistance over the DAP and water spraying treatments. Spraying DAP (S_2) or water (S_1) however did not influence the stomatal resistance.

The stomatal diffusive resistance was not influenced by the seasons. The interaction effect between the irrigation layouts and foliar spraying was found to be non-significant.

4.2.4. Transpiration rate (Table 27)

The transpiration rate was significantly influenced by different irrigation layouts in both the *kharif* seasons. Ridges and furrows (M_3) and flat ridges and furrows (M_2) resulted in significantly higher rate of transpiration and were on par with the each other. The rate of transpiration measured under the flat bed method was significantly lower than the other layouts. However, the effect of irrigation layouts on transpiration rate was found to be non-significant in *summer,* 2000.

The foliar spraying of combinations of DAP, KCl, boron and NAA (S_5) or DAP, KCl and boron (S_4) or application of DAP + KCl (S_3) recorded transpiration rates which were significantly lower than other treatment combinations and on par which each other. Foliar spraying of DAP (S_2) was found on par with water spraying with respect to transpiration rate. A similar effect was observed in all the seasons. The seasonal effect on

Table 27. Effect of irrigation layouts and foliar spraying on transpiration rate (TR) μg cm^{-1} s^{-1}

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	71.77	71.87	71.46	71.60	71.67	71.67	72.27	72.20	72.50	71.83	71.50	72.06	72.25	72.17	72.10	72.03	71.90	72.09
M_2	72.97	72.87	72.73	72.53	72.27	72.67	72.60	71.60	72.47	72.21	71.77	72.13	73.43	73.42	73.19	73.07	73.01	73.22
M_3	73.47	73.33	72.87	72.67	72.57	72.98	71.91	72.63	72.23	72.60	72.13	72.31	73.39	73.30	73.11	72.99	72.82	73.12
Mean	72.73	72.68	72.35	72.27	72.17		72.26	72.14	72.40	72.21	71.80		73.02	72.96	72.80	72.70	72.57	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.12	0.33	0.22	NS	0.08	0.23
S	0.10	0.22	0.24	NS	0.09	0.18
M at S	0.20	NS	0.44	NS	0.16	NS
S at M	0.18	NS	0.42	NS	0.15	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

transpiration rate was not observed. The interaction effect between irrigation layouts and foliar nutrition was found to be non-significant.

4.3. YIELD COMPONENTS

4.3.1. Number of pods per plant (Table 28)

The irrigation layouts had significant impact on the number of pods per plant in *kharif*, 99. Ridges and furrows resulted in higher number of pods per plant than the other two layouts but were on par with the flat beds. Significantly lower number of pods were produced under the flat ridges and furrows.

The different spray combinations had significant influence on pod number in all the three seasons. Foliar spraying of DAP + KCl + boron + NAA (S_5) and DAP, KCl and boron (S_4) recorded higher number of pods as compared to other treatments. This was followed by the foliar application of a combination of DAP + KCl (S_3). All the nutrient combinations were found to be superior over the water sprayed control plots in all the seasons studied.

Among the three seasons, lowest number of pods per plant was produced in *summer*, 2000 irrespective of the treatments. The interaction between irrigation layouts and foliar sprays was non-significant.

4.3.2. Total number of seeds per pod (Table 29)

The different irrigation layouts failed to impart any influence on the total number of seeds per pod, except in *kharif*, 2000. Ridges and furrows registered higher number of

Table 28. Effect of irrigation layouts and foliar spraying on number of pods per plant

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	85.27	88.57	88.73	92.80	94.47	89.97	80.93	82.97	83.73	84.07	87.30	83.80	88.20	91.83	94.53	92.87	93.80	92.25
M_2	81.33	81.40	80.87	83.40	87.07	82.81	80.37	83.60	81.90	94.13	86.17	83.23	87.57	88.20	90.90	92.63	94.80	90.82
M_3	92.87	90.60	94.07	93.53	92.36	92.69	81.20	82.33	84.97	83.43	84.73	83.33	87.17	92.47	93.27	93.13	95.87	92.38
Mean	86.49	86.85	87.89	89.91	91.30		80.83	82.97	83.53	83.88	86.07		87.64	90.83	92.90	92.88	94.82	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	1.22	3.40	0.84	NS	1.63	NS
S	1.58	3.27	0.80	1.66	1.22	2.51
M at S	2.74	NS	1.50	NS	2.49	NS
S at M	2.74	NS	1.39	NS	2.11	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

Table 29. Effect of irrigation layouts and foliar spraying on total number of seeds per pod

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	2.37	2.40	2.67	2.73	2.73	2.58	2.27	2.40	2.63	2.83	2.73	2.57	2.07	2.40	2.60	2.63	2.63	2.47
M_2	2.33	2.43	2.73	2.77	2.87	2.63	2.30	2.60	2.73	2.77	2.70	2.62	2.10	2.27	2.47	2.67	2.57	2.41
M_3	2.43	2.67	2.73	2.90	2.87	2.72	2.40	2.53	2.90	2.93	2.87	2.73	2.17	2.43	2.73	2.80	2.73	2.57
Mean	2.38	2.50	2.71	2.80	2.82		2.32	2.51	2.76	2.84	2.77		2.11	2.37	2.60	2.70	2.64	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.06	NS	0.08	NS	0.04	0.11
S	0.05	0.11	0.05	0.11	0.04	0.08
M at S	0.10	NS	0.12	NS	0.07	NS
S at M	0.09	NS	0.09	NS	0.07	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

seeds per pod and were on par with the flat beds. Total number of seeds per pod under the flat beds and flat ridges and furrows were on par.

The different spray combinations had significant influence on the total number of seeds per pod in all the three seasons. The combined application of DAP, KCl, boron and NAA (S_5), spraying DAP, KCl and boron (S_4) and the treatment comprising of DAP + KCl (S_3) produced higher number of seeds per pod and were on par with each other. Plants in the control plot registered significantly lowest number of seeds per pod than the other nutrient combinations in all the seasons.

The total number of seeds produced was not influenced by the different seasons. The irrigation layouts and foliar spray combinations failed to have any significant interaction effect on the production of seeds per pod.

4.3.4. Number of filled seeds per pod (Table 30)

The different irrigation layouts imparted a significant variation in number of filled seeds per pod in the *kharif* seasons. Under ridges and furrows, number of filled seeds produced was higher, and was on par with the flat beds. The number of filled seeds was lower under flat ridges and furrows and was on par with the flat beds in *kharif,* 99.

The foliar spraying of different combinations of nutrients imparted significant influence on number of filled seeds per pod in all the three seasons. The treatment comprising of DAP, KCl and boron (S_4) produced higher number of filled seeds per pod and was on par with the combination of DAP, KCl, boron and NAA (S_5). All the nutrient

Table 30. Effect of irrigation layouts and foliar spraying on number of filled seeds per pod

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	1.02	1.62	1.81	1.97	2.12	1.71	1.05	1.28	1.48	1.75	1.75	1.46	1.47	1.77	1.70	1.83	1.97	1.75
M_2	0.94	1.62	1.40	1.85	1.71	1.51	1.11	1.43	1.54	1.77	1.63	1.49	1.17	1.53	1.37	1.57	1.57	1.44
M_3	1.10	2.00	1.92	2.17	2.01	1.84	1.13	1.32	1.57	1.79	1.59	1.48	1.53	1.90	1.73	2.23	2.03	1.89
Mean	1.02	1.75	1.71	1.99	1.95		1.09	1.34	1.53	1.77	1.66		1.39	1.73	1.60	1.88	1.85	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.07	0.20	0.03	NS	0.06	0.15
S	0.08	0.16	0.08	0.17	0.07	0.14
M at S	0.12	NS	0.13	NS	0.12	NS
S at M	0.14	NS	0.14	NS	0.12	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

combinations were found to be superior in their effect on filled seeds per pod over the water sprayed control.

The number of filled seeds was generally lower in *summer* than in *kharif* seasons, irrespective of the treatments tried. The interaction effect between irrigation layouts and foliar sprays was not significant.

4.3.5. Seed filling percentage (Table 31)

The different irrigation layouts had significant effect on the seed filling percentage only in *kharif, 99*. The filling percentage was higher under ridges and furrows and was on par with the flat beds. The flat ridges and furrows registered significantly lowest values of seed filling percentage. The effect of irrigation layouts on seed filling percentage was non-significant in *summer* and *kharif* seasons of 2000.

The foliar application of nutrient combinations significantly influenced the seed filling percentage in both the *kharif* seasons studied. Combined application of DAP, KCl, boron and NAA (S_5) and the combination of DAP, KCl and boron (S_4) recorded significantly higher seed filling percentage and were on par with each other in *kharif,* 2000. These two treatments were on par with foliar spray of DAP + KCl (S_3) in *kharif, 99*. All the nutrient combinations registered significantly higher values of seed filling percentage over the water sprayed control. In *summer* though there was no significant influence of different nutrient combinations on the seed filling percentage, they registered numerically higher values over the water spraying treatment.

Table 31. Effect of irrigation layouts and foliar spraying on seed filling percentage

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	47.30	53.87	61.08	63.61	63.58	57.89	49.63	56.70	53.47	59.33	52.57	54.34	55.13	56.17	59.60	62.90	60.04	58.76
M_2	45.99	52.53	55.76	59.13	60.20	54.73	53.47	51.17	58.00	52.30	62.33	55.45	54.10	56.0	59.43	65.73	65.13	60.08
M_3	51.66	56.73	59.95	62.24	62.15	58.55	56.04	56.98	59.47	60.88	60.34	58.74	55.63	59.10	61.44	64.48	62.99	60.73
Mean	48.32	54.38	58.93	61.66	61.98		53.05	54.95	56.98	57.50	58.42		54.96	57.09	60.16	64.37	62.72	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.49	1.36	0.63	NS	1.35	NS
S	1.55	3.20	0.91	1.88	2.26	NS
M at S	2.45	NS	1.55	NS	3.76	NS
S at M	2.68	NS	1.58	NS	3.92	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

Seed filling percentage was lower in *kharif,* 99 and *summer,* 2000 as compared to *kharif,* 2000. There was no significant interaction effect between irrigation layouts and foliar sprays on seed filling percentage.

4.3.6. Test weight (Table 32)

The different irrigation layouts had a significant effect on the test weight in *summer,* 2000. Ridges and furrows registered higher values of test weight over other methods and the flat ridges and furrows registered significantly lower test weight. However in *kharif* seasons, irrigation layouts had no significant effect on test weight.

The foliar nutrient combinations produced significant impact on test weight in all the three seasons studied. The combination of DAP, KCl, boron and NAA (S_5) registered higher values of test weight, however on par with the combination excluding NAA (S_4) in the *kharif* seasons. But in *summer,* 2000 combination of DAP, KCl and boron (S_4) was superior and was on par with application of DAP, KCl, boron and NAA (S_5). All the nutrient combinations recorded significantly higher test weight as compared to water sprayed control plots, irrespective of the seasons studied. In general lower values of test weight were recorded in the *summer* season as compared to both the *kharif* seasons studied. The interaction effect between irrigation layouts and foliar nutrition was non-significant in all seasons.

4.3.7. Grain yield (Table 33)

The different irrigation layouts had a significant effect on grain yield of soybean in *kharif,* 99 and *summer,* 2000. Among the different irrigation layouts studied, ridges and

Table 32. Effect of irrigation layouts and foliar spraying on test weight (g)

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	10.68	11.31	11.74	11.67	11.60	11.40	10.43	10.78	11.14	11.78	11.62	11.15	11.06	11.56	11.86	12.12	12.00	11.72
M_2	10.36	10.83	11.09	11.47	11.82	11.11	10.26	10.62	10.98	11.35	11.04	10.85	10.50	11.08	11.40	11.46	11.60	11.21
M_3	10.38	10.99	11.87	11.62	11.96	11.36	10.87	11.02	11.52	11.74	11.61	11.35	10.61	11.46	11.62	12.06	12.09	11.57
Mean	10.47	11.04	11.56	11.58	11.79		10.52	10.81	11.21	11.62	11.42		10.72	11.36	11.63	11.88	11.89	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.23	NS	0.10	0.27	0.31	NS
S	0.14	0.28	0.10	0.21	0.10	0.22
M at S	0.31	NS	0.18	NS	0.35	NS
S at M	0.24	NS	0.18	NS	0.18	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

furrows resulted in higher grain yield as compared to the other layouts in all the three seasons. The yield produced under flat beds was significantly lower over the other two layouts irrespective of the seasons studied. The irrigation layouts failed to influence the grain yield significantly in *kharif*, 2000.

The foliar application of different nutrient combinations had a significant influence on grain yield in all the three seasons. Among the foliar sprays compared combined application of DAP, KCl, boron and NAA (S_5) and application of DAP, KCl and boron (S_4) registered significantly higher values of grain yield which was on par with each other in *kharif*, 99 and *summer*, 2000. These two treatments were on par with the combination of DAP + KCl (S_3) in *kharif*, 2000. All these nutrient combinations recorded significantly higher grain yield over the water sprayed plots in the three seasons.

There was significant interaction effect between the irrigation layouts and foliar nutrition on grain yield in *kharif*, 99. At different irrigation layouts, spraying of DAP + KCl + boron + NAA (S_5) recorded the maximum yield and it was on par with application of DAP + KCl + boron (S_4). In all the irrigation layouts, water spraying (S_1) recorded the lowest yield. At different spray schedules ridges and furrows (M_3) recorded the maximum grain yield and the least was recorded by flat beds (M_1). The maximum yield was recorded by spraying DAP + KCl + boron + NAA under ridges and furrows (M_3S_5) followed by spraying of DAP + KCl + boron under ridges and furrows (M_3S_4). The grain yield recorded under flat beds applied with water, (M_1S_1) recorded significantly lower grain yield. Such interaction effect between irrigation layouts and foliar nutrition was not observed in

Table 33. Effect of irrigation layouts and foliar spraying on grain yield (kg ha^{-1})

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	1193	1286	1368	1489	1547	1376	1163	1177	1274	1261	1288	1232	1296	1358	1420	1496	1526	1419
M_2	1370	1386	1467	1570	1611	1481	1245	1285	1333	1404	1417	1336	1421	1416	1505	1563	1591	1499
M_3	1372	1455	1521	1664	1633	1529	1319	1383	1510	1590	1645	1489	1468	1643	1721	1771	1764	1673
Mean	1312	1375	1452	1574	1597		1242	1282	1372	1418	1450		1395	1472	1548	1610	1627	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	16.02	44.49	33.61	93.31	88.75	NS
S	13.82	28.52	26.15	53.96	51.42	106.13
M at S	26.74	63.03	52.63	NS	119.26	NS
S at M	23.94	49.40	45.29	NS	89.06	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

summer and *kharif* seasons of 2000. The grain yield was lower in *summer* as compared to *kharif* seasons.

4.3.8. Haulm yield (Table 34)

The irrigation layouts had no significant influence on haulm yield in all the three seasons studied. The influence of foliar sprays was observed only in the *summer* season. The treatments consisting of different combinations of nutrients (S_2, S_3 S_4 and S_5) were significantly superior over the control treatment receiving water spray. The haulm yield recorded in *summer* was slightly lower as compared to the *kharif* seasons. There was no significant interaction effect between irrigation layouts and foliar sprays.

4.3.9. Harvest Index (Table 35)

There was significant effect of varying irrigation layouts on the harvest index in *summer,* 2000. The ridges and furrow method was significantly superior over the other layouts with respect to its effect on harvest index, which was followed by flat ridges and furrows. The flat bed method recorded significantly lower values of harvest index. The different irrigation layouts failed to have any impact on harvest index in the *kharif* seasons.

The foliar application of different combination of nutrients had a significant effect on harvest index in *kharif,* 99 and *summer,* 2000. Application of different combinations of nutrients under treatments S_2, S_3 S_4 and S_5 were superior over the control treatment receiving water spraying. The seasonal influence on harvest index was not observed. There was no significant interaction effect between irrigation layouts and foliar sprays.

Table 34. Effect of irrigation layouts and foliar spraying on haulm yield (kg ha^{-1})

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	2841	2690	2756	2583	2799	2734	2321	2633	2475	2603	2564	2517	2359	2523	2531	2588	2539	2508
M_2	2578	2837	2718	2785	2611	2706	2148	2401	2484	2463	2450	2389	2317	2372	2370	2364	2459	2376
M_3	2652	2783	2620	2596	2450	2620	2235	2422	2543	2393	2382	2395	2602	2701	2619	2530	2504	2591
Mean	2690	2770	2698	2655	2620		2234	2482	2501	2486	2465		2426	2532	2506	2494	2500	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	102.01	NS	53.93	NS	126.57	NS
S	76.71	NS	50.48	104.18	54.64	NS
M at S	156.61	NS	94.99	NS	152.27	NS
S at M	132.87	NS	87.43	NS	94.64	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

Table 35. Effect of irrigation layouts and foliar spraying on harvest index

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	33.39	34.76	34.47	35.45	35.22	34.66	33.86	33.83	35.00	34.19	34.11	34.20	33.42	33.20	33.17	33.25	32.73	33.15
M_2	34.69	35.93	36.23	37.00	36.47	36.06	32.00	34.26	34.52	34.03	33.76	33.71	33.52	32.37	32.34	34.37	34.38	33.60
M_3	35.56	37.54	36.75	39.04	38.20	37.42	34.07	34.42	35.04	36.06	35.34	34.99	32.30	32.65	34.44	34.92	34.78	33.82
Mean	34.55	36.08	35.82	37.16	36.63		33.31	34.17	34.85	34.76	34.40		33.08	32.74	33.65	34.18	33.96	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.09	0.24	1.06	NS	0.87	NS
S	0.33	0.67	0.42	0.88	0.55	NS
M at S	0.51	NS	1.25	NS	1.22	NS
S at M	0.56	NS	0.73	NS	0.96	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

4.3.10. Protein content (Table 36)

Irrigation layouts failed to influence the protein content of soybean in all the three seasons tried. The nutrient sprays had a significant effect on protein content in summer and *kharif,* 2000. Among the nutrient combinations compared, foliar spray including DAP (S_2, S_3, S_4 and S_5) recorded significantly higher content of protein as compared to water spray and were on par with each other. Foliar spray of DAP recorded higher protein content followed by the other combinations. The content of protein recorded under control plots was significantly lower than foliar spraying of nutrient combinations, in both the seasons.

The protein content recorded in *summer* was lower than in *kharif* irrespective of the treatments. There was no interaction effect between irrigation layouts and foliar sprays.

4.3.11. Oil content (Table 37)

The oil content of soybean seeds was significantly influenced by the different layouts of irrigation only in *kharif, 2000.* The ridges and furrow method was significantly superior over the other layouts in its effect on oil content. The flat ridges and furrow was on par with the flat beds.

The different nutrient combinations produced significant effect on the oil content in all the three seasons studied. Among the different nutrient combinations, combination of DAP and KCl with or without boron (S_3 and S_4) registered higher content of oil irrespective of the seasons studied. This was followed by the combination including NAA (S_5). All the nutrient combinations recorded significantly higher values of oil content over the water sprayed control, in *kharif,* 99. However in *kharif* and summer, 2000, this

Table 36. Effect of irrigation layouts and foliar spraying on protein content (%)

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	39.31	40.66	40.20	40.53	40.14	40.17	39.44	40.37	38.99	40.11	39.96	39.77	39.32	40.59	40.57	40.42	40.85	40.35
M_2	38.88	40.44	40.06	39.97	40.49	39.97	39.57	40.64	40.07	39.95	39.32	39.91	39.58	40.80	40.35	41.06	40.56	40.47
M_3	40.99	41.06	40.27	40.52	40.02	40.57	39.13	40.56	39.52	39.86	40.70	39.95	39.22	40.89	41.01	40.23	40.21	40.31
Mean	39.72	40.72	40.17	40.34	40.22		39.38	40.52	39.52	39.97	39.99		39.37	40.76	40.64	40.57	40.54	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.33	NS	0.37	NS	0.10	NS
S	0.38	NS	0.35	0.72	0.21	0.44
M at S	0.67	NS	0.66	NS	0.34	NS
S at M	0.65	NS	0.61	NS	0.37	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % $S_3 - S_2$ + KCl 1 % $S_4 - S_3$ + Boron 0.2 % $S_5 - S_4$ + NAA 40 ppm

Table 37. Effect of irrigation layouts and foliar spraying on oil content (%)

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	18.70	19.67	19.74	19.15	18.90	19.23	20.35	20.95	20.88	21.30	21.15	21.12	19.28	19.57	19.60	19.93	20.09	19.69
M_2	18.31	18.25	19.26	19.62	19.04	18.90	19.88	19.31	21.28	21.04	21.39	20.78	18.68	19.60	20.34	20.00	20.07	19.74
M_3	18.93	19.04	19.35	19.07	19.29	19.14	20.84	21.75	20.85	21.33	21.10	21.37	19.88	19.86	20.94	21.18	20.19	20.41
Mean	18.65	18.99	19.45	19.28	19.08		20.36	20.67	21.00	21.22	21.21		19.28	19.68	20.29	20.37	20.12	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.17	NS	0.18	NS	0.12	0.33
S	0.16	0.33	0.21	0.44	0.27	0.55
M at S	0.30	NS	0.38	NS	0.43	NS
S at M	0.27	NS	0.37	NS	0.46	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

treatment was on par with foliar spray of 2 % DAP. There was no significant interaction effect between irrigation layouts and foliar sprays. The oil content was slightly higher in *summer* than in *kharif* season.

4.4. Nutrient uptake

4.4.1. Nitrogen uptake (Table 38 & 39)

The different irrigation layouts failed to have any influence on the nitrogen uptake at 60 DAS in all the three seasons. Foliar spray treatments showed perceptible change on N uptake in 60 DAS. All the nutrient combinations including DAP and KCl registered significantly higher values of N uptake over the DAP foliar spray in *kharif,* 99. In summer and *kharif,* 2000 seasons these combinations were on par with DAP. Lower values of N uptake were registered under control irrespective of the season studied.

The irrigation layouts failed to produce any significant influence on N uptake at 90 DAS, however the foliar spray combinations resulted in significant effect on N uptake. The DAP spray was significantly superior over the water spraying treatment. The combinations including KCl and DAP with or without boron and NAA (S_3 to S_5) recorded significantly higher N uptake over DAP spray and were on par with each other. However inclusion of NAA failed to have any impact on N uptake while boron showed a noticeable effect on N uptake.

The nitrogen uptake was lower in summer than in the *kharif* seasons. The interaction effect between irrigation layouts and foliar sprays was found non-significant.

Table 38. Effect of irrigation layouts and foliar spraying on nitrogen uptake at 60 DAS (kg ha^{-1})

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	82.51	86.43	86.10	86.36	87.10	85.69	74.78	80.13	84.04	84.06	83.77	81.35	81.07	84.95	85.96	86.05	86.86	84.98
M_2	83.45	87.64	88.91	88.74	90.19	87.79	78.48	80.64	82.66	84.78	82.79	81.87	81.95	86.28	87.42	86.47	87.54	85.93
M_3	83.62	88.07	87.69	88.97	89.61	87.59	81.55	86.04	87.96	85.99	85.42	85.39	82.05	86.51	87.03	86.43	86.12	85.63
Mean	83.19	87.38	87.57	88.02	88.97		78.27	82.27	84.89	84.94	83.99		81.69	85.91	86.80	86.32	86.84	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	2.17	NS	2.43	NS	0.97	NS
S	0.63	1.29	0.39	0.81	0.27	0.56
M at S	2.37	NS	2.51	NS	1.06	NS
S at M	1.09	NS	0.68	NS	0.47	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

Table 39. Effect of irrigation layouts and foliar spraying on nitrogen uptake at 90 DAS (kg ha^{-1})

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	101.4	108.2	108.9	112.0	111.9	108.5	103.9	111.3	115.5	114.9	114.3	112.0	102.5	107.5	109.4	110.9	109.7	108.0
M_2	107.7	112.2	114.6	115.0	116.0	113.1	104.2	110.9	112.4	114.5	114.9	111.4	99.6	104.4	104.6	106.1	105.2	103.9
M_3	106.5	111.6	113.9	113.8	115.1	112.2	103.7	110.1	113.1	113.6	113.5	110.8	107.5	113.7	115.3	114.5	114.7	113.1
Mean	105.2	110.6	112.5	113.6	114.4		103.9	110.8	113.7	114.3	114.2		103.2	108.5	109.8	110.5	109.9	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	3.10	NS	1.36	NS	2.99	NS
S	0.81	1.67	1.01	2.08	0.75	1.55
M at S	3.34	NS	2.07	NS	3.21	NS
S at M	1.40	NS	1.75	NS	1.30	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

4.4.2. Phosphorus uptake (Table 40 & 41)

The different irrigation layouts showed significant influence on P uptake at 60 DAS only in the summer season, in which the ridges and furrows registered significantly higher P uptake than the other two layouts.

The foliar spraying treatments exhibited significant effect on P uptake at 60 DAS. Spraying DAP was found to be significantly superior over the control in all the seasons studied. Foliar spraying of combination of DAP and KCl with or without boron and NAA (S_3, S_4 and S_5) registered significantly higher values of P uptake over DAP spray in *kharif,* 99 and were par with DAP spray in the summer and *kharif* seasons of 2000. The inclusion of boron (S_4) had an appreciable impact while the NAA addition failed to have consistent and noticeable effect on P uptake.

The irrigation layouts had a significant impact on P uptake at 90 DAS in *kharif, 99* and summer, 2000. In both seasons, ridges and furrows recorded higher values of P uptake over the other two layouts. The foliar treatments had significant influence on P uptake in all the three seasons. The different nutrient combinations had a significant favourable effect on P uptake and resulted in significantly higher P uptake than the control plots, in all the three seasons. The different nutrient combinations (S_2 to S_5) were on par with each other.

4.4.3. Potassium uptake (Table 42 & 43)

The irrigation layouts failed to impart any significant influence on K uptake at 60 DAS. Among the foliar treatments, spraying of the nutrient combinations was significantly

Table 40. Effect of irrigation layouts and foliar spraying on phosphorus uptake at 60 DAS (kg ha^{-1})

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	8.79	9.56	9.62	9.67	9.64	9.46	9.25	9.97	10.14	10.03	10.14	9.91	9.62	10.72	10.67	10.89	10.98	10.57
M_2	8.58	9.37	9.54	9.75	9.66	9.38	9.18	9.92	10.09	10.16	10.12	9.89	10.06	10.66	10.86	11.17	10.86	10.72
M_3	8.78	9.40	9.81	9.77	9.81	9.51	9.53	10.26	10.14	10.21	10.27	10.08	9.88	10.84	11.11	11.53	11.13	10.89
Mean	8.72	9.44	9.66	9.73	9.70		9.32	10.05	10.12	10.13	10.17		9.85	10.74	10.88	11.19	10.99	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.31	NS	0.03	0.10	0.20	NS
S	0.06	0.13	0.05	0.11	0.13	0.28
M at S	0.32	NS	0.09	NS	0.29	NS
S at M	0.11	NS	0.09	NS	0.23	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % $S_3 – S_2$ + KCl 1 % $S_4 – S_3$ + Boron 0.2 % $S_5 – S_4$ + NAA 40 ppm

Table 41. Effect of irrigation layouts and foliar spraying on phosphorus uptake at 90 DAS (kg ha^{-1})

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	17.01	18.35	18.63	19.22	19.16	18.48	17.17	20.10	20.74	20.24	20.61	19.77	13.78	16.08	16.61	17.02	17.07	16.11
M_2	18.81	19.79	19.83	20.09	19.76	19.66	15.20	17.02	18.05	17.89	17.49	17.13	15.30	17.71	17.69	18.04	17.79	17.30
M_3	18.88	20.17	20.11	20.53	19.97	19.93	13.09	15.37	15.80	15.69	15.55	15.10	16.05	18.48	18.67	18.52	18.76	18.09
Mean	18.23	19.44	19.52	19.94	19.63		15.16	17.50	18.19	17.94	17.88		15.04	17.42	17.66	17.86	17.87	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.25	0.70	0.22	0.61	0.55	NS
S	0.19	0.39	0.29	0.61	0.20	0.42
M at S	0.39	NS	0.51	NS	0.64	NS
S at M	0.33	NS	0.51	NS	0.35	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

Table 42. Effect of irrigation layouts and foliar spraying on potassium uptake at 60 DAS (kg ha^{-1})

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	52.55	53.62	56.84	59.02	59.07	56.22	52.17	53.25	56.30	58.07	58.03	55.56	50.07	51.18	54.52	56.52	56.10	53.68
M_2	52.42	53.34	56.14	58.02	58.01	55.59	52.70	53.52	56.78	57.84	57.27	55.62	51.73	52.53	55.83	57.08	57.92	55.02
M_3	53.37	54.10	57.25	58.37	58.81	56.38	52.96	54.06	56.68	58.25	58.33	56.05	51.97	53.11	56.12	56.99	56.81	55.00
Mean	52.78	53.69	56.74	58.47	58.63		52.61	53.61	56.58	58.05	57.88		51.25	52.27	55.49	56.86	56.94	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	0.76	NS	0.51	NS	0.98	NS
S	0.34	0.70	0.26	0.54	0.23	0.48
M at S	0.92	NS	0.65	NS	1.05	NS
S at M	0.59	NS	0.46	NS	0.40	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % $S_3 - S_2$ + KCl 1 % $S_4 - S_3$ + Boron 0.2 % $S_5 - S_4$ + NAA 40 ppm

Table 43. Effect of irrigation layouts and foliar spraying on potassium uptake at 90 DAS (kg ha^{-1})

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	67.30	66.22	70.73	72.62	73.89	70.15	60.11	62.02	65.73	66.10	66.90	64.17	64.51	65.75	69.13	70.57	70.94	68.18
M_2	66.89	69.29	73.61	75.26	75.24	72.06	61.33	63.44	68.71	69.39	70.08	66.59	66.23	68.16	72.47	73.35	73.43	70.73
M_3	67.27	69.85	74.04	74.45	75.11	72.14	62.94	64.39	68.83	70.72	71.02	67.58	68.14	69.87	73.70	75.27	75.54	72.50
Mean	67.15	68.45	72.79	74.11	74.74		61.46	63.28	67.76	68.74	69.33		66.29	67.93	71.77	73.06	73.30	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	2.25	NS	1.62	NS	0.28	NS
S	0.81	1.67	0.44	0.90	0.23	0.48
M at S	2.57	NS	1.76	NS	0.46	NS
S at M	1.40	NS	0.76	NS	0.40	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

superior over the control. Foliar spraying of DAP, KCl, boron and NAA and the combination excluding NAA (S_5 and S_4) were superior over other treatments and on par with each other. Foliar spraying of DAP either alone or in combination with KCl registered significantly higher K uptake over the water spraying treatment. A similar trend was observed in all the seasons and stages studied.

4.5. Post harvest soil nutrient status

4.5.1. Soil available nitrogen (Table 44)

The different irrigation layouts failed to have any influence on the soil available nitrogen status at harvest in all the three seasons studied. Foliar nutrition however showed a marked impact on the available nitrogen status of soil in all three seasons. Application of different combinations of nutrients viz., DAP, KCl, boron and NAA under treatments S_2, S_3, S_4 and S_5 were found to have a significant influence on the available nitrogen status over the water sprayed control treatment and were on par with each other. In all the three seasons, there was a perceptible improvement in soil nitrogen status as compared to the initial nitrogen level of soil.

4.5.2. Soil available phosphorus (Table 45)

The irrigation layouts had a significant impact on available phosphorus at harvest only in *kharif*, 99. Ridges and furrows registered higher values of available phosphorus and were found on par with the flat ridges and furrows. These two layouts recorded significantly superior values of available phosphorus over the flat beds.

Table 44. Effect of irrigation layouts and foliar spraying on post- harvest soil nitrogen (kg ha^{-1})

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	209.8	216.7	219.1	215.8	219.2	216.1	241.4	251.0	251.2	253.3	255.0	250.4	230.1	238.2	234.5	235.5	234.8	234.6
M_2	209.5	216.7	218.9	217.1	218.6	216.1	242.7	251.2	253.8	258.2	253.8	251.9	226.7	237.1	232.5	236.9	235.1	233.6
M_3	213.4	217.7	218.7	217.4	217.7	217.0	245.4	256.8	258.8	255.9	255.9	254.6	229.7	239.4	239.1	238.5	238.3	237.0
Mean	210.9	217.1	218.9	216.8	218.5		243.2	253.0	254.6	255.8	254.9		228.8	238.2	235.4	236.9	236.0	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	1.01	NS	1.33	NS	2.17	NS
S	0.91	1.89	1.88	3.88	1.07	2.21
M at S	1.74	NS	3.20	NS	2.73	NS
S at M	1.58	NS	3.26	NS	1.86	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

Table 45. Effect of irrigation layouts and foliar spraying on post- harvest soil phosphorus (kg ha^{-1})

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	14.87	16.27	15.73	16.71	15.99	15.91	16.50	19.56	18.59	18.24	18.48	18.27	17.78	19.16	18.61	19.09	18.71	18.67
M_2	14.68	16.02	16.05	16.68	16.61	16.01	18.07	19.63	18.44	18.72	18.98	18.77	17.25	18.68	19.09	19.15	19.26	18.68
M_3	15.11	16.66	17.0	17.10	17.45	16.66	17.43	19.51	19.61	19.56	18.72	18.96	16.82	18.84	19.32	19.07	19.04	18.62
Mean	14.88	16.31	16.26	16.83	16.68		17.33	19.56	18.88	18.84	18.72		17.28	18.89	19.01	19.10	19.00	

	Kharif' 99 SEd	Kharif' 99 CD (P = 0.05)	Summer' 2000 SEd	Summer' 2000 CD (P = 0.05)	Kharif' 2000 SEd	Kharif' 2000 CD (P = 0.05)
M	0.21	0.59	0.25	NS	0.17	NS
S	0.20	0.42	0.28	0.59	0.20	0.41
M at S	0.38	NS	0.51	NS	0.35	NS
S at M	0.35	NS	0.49	NS	0.34	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

Among the foliar spray combinations the different nutrients and hormone sprayed as DAP alone (S_2), DAP + KCl (S_3), DAP + KCl + boron (S_4) and DAP + KCl + boron + NAA (S_5) were all found significantly superior over the water sprayed control treatment. All the treatments containing DAP in their combination were comparable with each other.

4.5.3. Soil available potassium (Table 46)

The irrigation layouts had a significant influence on soil available potassium at harvest only in *kharif*, 99. Ridges and furrows registered higher values of available K and were on par with the values recorded under flat ridges and furrows. The available K status under flat beds was significantly lower than other two layouts.

The available K status was influenced significantly by foliar application of different combination of nutrients and growth hormones. In all the seasons studied, the combined spray of DAP, KCl, boron and NAA (S_5) registered higher available K and was on par with the same combination excluding NAA (S_4). The water spraying treatment resulted in significantly lower values of available K status. In both the summer and *kharif* seasons of 2000, the combinations including KCl under treatments S_3, S_4 and S_5 registered significantly higher available K status and were on par with each other. The treatments receiving DAP spray (S_2) and water spray (S_1) resulted in significantly lower available K than other treatments and were on par with each other.

4.6. Water requirement and use efficiency (Table 47 & 48)

The total water used varied according to the irrigation water applied and the amount of effective rainfall received during the crop period. The irrigation water applied

Table 46. Effect of irrigation layouts and foliar spraying on post-harvest soil potassium (kg ha^{-1})

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	495.5	495.9	504.9	505.1	508.3	501.9	510.7	510.6	523.1	521.5	527.8	518.8	517.1	518.5	524.7	527.1	529.7	523.4
M_2	502.4	505.5	514.6	518.3	515.8	511.3	510.6	512.6	522.8	522.3	521.7	518.0	516.4	516.2	522.4	522.5	523.8	520.3
M_3	510.0	512.7	519.4	522.3	522.7	517.4	512.8	514.5	525.6	524.7	525.9	520.7	514.4	516.8	526.6	526.8	528.9	522.7
Mean	502.6	504.7	513.0	515.2	515.6		511.4	512.6	523.8	522.8	525.2		515.9	517.2	524.6	525.5	527.5	

	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)	SEd	CD (P = 0.05)
M	2.58	7.15	1.33	NS	1.26	NS
S	0.83	1.71	1.16	2.39	1.03	2.13
M at S	2.88	NS	2.23	NS	1.77	NS
S at M	1.44	NS	2.01	NS	1.79	NS

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

Table 47. Influence of irrigation layouts on water requirement (mm) and WUE (kg ha^{-1} mm^{-1})

Treatment	No. of irrigations	Irrigation water applied (mm)	Effective rainfall (mm)	Total water used (mm)	Yield (kg ha^{-1})	WUE (kg ha^{-1} mm^{-1})
			Kharif 99			
M_1	6	300	169	469	1376	2.93
M_2	6	96	169	265	1481	5.62
M_3	6	144	169	313	1529	4.88
			Summer 2000			
M_1	8	400	70	470	1232	2.62
M_2	8	128	70	198	1336	6.75
M_3	8	192	70	262	1489	5.68
			Kharif 2000			
M_1	4	200	308	508	1419	2.79
M_2	4	64	308	372	1499	4.03
M_3	4	96	308	404	1673	4.14

Table 48. Effect of irrigation layouts and foliar spraying on Water Use Efficiency (WUE)

	Kharif' 99						Summer' 2000						Kharif' 2000					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1	2.54	2.74	2.92	3.17	3.30	2.93	2.47	2.50	2.71	2.68	2.74	2.62	2.55	2.67	2.79	2.94	3.00	2.79
M_2	5.17	5.23	5.53	5.92	6.08	5.59	6.28	6.49	6.73	7.09	7.15	6.75	3.82	3.81	4.04	4.20	4.28	4.03
M_3	4.38	4.65	4.86	5.32	5.22	4.88	5.03	5.28	5.76	6.07	6.28	5.68	3.63	4.07	4.26	4.38	4.37	4.14
Mean	4.03	4.21	4.44	4.80	4.87		4.59	4.75	5.07	5.28	5.39		3.33	3.52	3.69	3.84	3.88	

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

was higher (50 mm) in the flat beds, lower under flat ridges and furrows (16 mm) and under ridges and furrows (24 mm). Among the seasons, higher number of irrigation was given in summer, since the rainfall received was lower. The lowest number of irrigations were given in *kharif, 2000*. The amount of rainfall obtained in this season was highest and hence the total water used was also higher and WUE remained lower in this season.

The water use efficiency is a tool to assess the productivity of a crop per unit of water used. It is computed by taking into account the economic yield of a crop and dividing it by the total water use and expressed in kg ha^{-1} mm^{-1}. The WUE indicated that among the three irrigation layouts the highest yield per unit of water used was recorded under the flat ridges and furrows in *kharif* 99 and summer, 2000. However in *kharif,* 2000 such differences between the flat ridges and furrows and ridges and furrows were not observed. In all the three seasons the flat beds registered the lowest water use efficiency.

4.7. Economics (Table 49)

Highest net returns were obtained under ridges and furrows treatment and spray combination of DAP, KCl and boron (M_3S_4) in *kharif,* 2000. This combination resulted in increased net returns of Rs. 2755 ha^{-1} at an additional cost of Rs. 275 ha^{-1}. Lowest net returns and BCR were obtained under flat beds receiving water spray (M_1S_1). Among the irrigation layouts studied, ridges and furrows resulted in higher net returns and B:C ratio over the other two layouts.

While comparing the different spray combinations, foliar spraying of DAP alone (S_2) failed to result in higher returns over water spraying in all the seasons. Among the

Table 49. Economics of different irrigation layouts and foliar spraying

Treatment	Cost of cultivation ($Rs ha^{-1}$)			Gross returns ($Rs ha^{-1}$)			Net returns ($Rs ha^{-1}$)			B:C Ratio		
	Kharif 99	Summer 2000	Kharif 2000	Kharif 99	Summer 2000	Kharif 2000	Kharif 99	Summer 2000	Kharif 2000	Kharif 99	Summer 2000	Kharif 2000
M_1S_1	10,862	11532	10,192	11,930	11,630	12,960	1068	98	2768	1.10	1.01	1.27
M_1S_2	11,046	11,716	10,376	12,860	11,770	13,580	1814	54	3204	1.16	1.00	1.31
M_1S_3	11,089	11,759	10,419	13,680	12,740	14,200	2591	981	3781	1.23	1.08	1.36
M_1S_4	11,185	11,855	10,515	14,890	12,610	14,960	3705	755	4445	1.33	1.06	1.42
M_1S_5	11,217	11,887	10,547	15,470	12,880	15,260	4253	993	4713	1.38	1.08	1.45
M_2S_1	9989	10,203	9775	13,700	12,450	14,210	3711	2247	4435	1.37	1.22	1.45
M_2S_2	10,173	10,387	9959	13,860	12,850	14,160	3687	2463	4201	1.36	1.24	1.42
M_2S_3	10,216	10,430	10,002	14,670	13,330	15,050	4454	2900	5048	1.43	1.28	1.50
M_2S_4	10,312	10,526	10,098	15,700	14,040	15,630	5388	3514	5532	1.52	1.33	1.55
M_2S_5	10,344	10,558	10,130	16,110	14,170	15,910	5766	3612	5780	1.56	1.34	1.57
M_3S_1	10,088	10,410	9766	13,720	13,190	14,680	3632	2780	4914	1.36	1.27	1.51
M_3S_2	10,272	10,594	9950	14,550	13,830	16,430	4278	3236	6480	1.42	1.30	1.65
M_3S_3	10,315	10,637	9993	15,210	15,100	17,210	4895	4463	7217	1.47	1.42	1.72
M_3S_4	10,411	10,733	10,089	16,640	15,900	17,710	6229	5127	7621	1.60	1.48	1.75
M_3S_5	10,443	10,765	10,121	16,330	16,450	17,640	5887	5685	7519	1.56	1.53	1.74

Data statistically not analysed

M_1 – Flat beds M_2 – Flat ridges and furrows M_3 – Ridges and furrows

S_1 – Control S_2 – DAP 2 % S_3 – S_2 + KCl 1 % S_4 – S_3 + Boron 0.2 % S_5 – S_4 + NAA 40 ppm

seasons tried, highest net returns and BCR were obtained in *kharif,* 2000 as compared to the other two seasons and net returns obtained in summer was lower as compared to the *kharif* seasons.

DISCUSSION

CHAPTER V

DISCUSSION

The results presented in the previous chapter provided information on the effect of irrigation layouts and foliar nutrition on growth, yield attributes and yield besides water requirement and water use efficiency, plant water relations and nutrient uptake of soybean. The results of the experiments presented are discussed below.

5.1. Effect of seasons on growth and yield

The growth, yield components and grain yield were affected by the seasons in which the crop was cultivated and were higher in *kharif* season than in summer. An increase of 8.05 per cent of grain yield was recorded in *kharif,* 99 over summer, 2000 and 13.1 per cent in *kharif* 2000 over summer 2000. This is mainly due to the weather that prevailed during the cropping period.

The temperature recorded during grain formation and grain filling is an important character, which decides the crop yield. Lower temperature recorded during the flowering stage resulted in formation of higher number of grains per plant (Reddy and Reddi, 1992). Similarly in the present experiment lower temperature (29.3-31.9°C) was recorded during reproductive stage in *kharif,* 2000 as compared to the other two seasons. Also, the duration was 110 days in *kharif,* 2000 as against 102 and 100 days in *kharif,* 99 and summer 2000. This explains the higher yield obtained in *kharif,* 2000 as compared to other two seasons. Moreover, in summer maximum temperature had detrimental effect on pollination, pollen desiccation, seed setting and seed filling. The higher temperature (30.5-35.9°C) caused dehydration of pollen grain and stigma resulting in abortion of flowers and pods and decreased the pod setting efficiency. The sensitivity of cell division and expansion in leaf tissue to temperature may be the major contributing factor for variation among the seasons (Thomas and Raper, 1978). This probably might have reduced the yield of summer crops compared to *kharif* crops.

Rainfall is an important factor, which not only affects the crop growth and yield, but also the water consumption and water use efficiency. Between the two *kharif* seasons, higher yield was recorded in *kharif*, 2000 over *kharif*, 99 which was mainly due to higher rainfall received especially during the vegetative stage of crop growth. The amount, distribution and number of rainy days in *kharif*, 2000 was favourable for higher grain yield. During this season, a total of 422 mm of rainfall was received in 26 rainy days, out of which only 103 mm was ineffective and the rainfall during this season was evenly distributed. However in *kharif*, 99, out of 335 mm of rainfall received, 166 mm was ineffective since the distribution was unfavourable and received in 23 rainy days. So not only the quantity but also the utilizable portion of rainfall was low in *kharif*, 99. In summer the total rainfall received was only 70 mm and the entire amount was effective. Though the summer crop was given additional irrigations, yield was lower.

The mean relative humidity was higher in the *kharif* seasons (69.8 and 70.4 per cent in *kharif* 99 and 2000 respectively) and relatively lower in summer (63.7 per cent). This is because the dry atmosphere is affected marginally by irrigation and decreased the growth of crops (Reddy and Reddi, 1992). The relative humidity is positively associated with shoot growth which is due to increased supply of assimilates to vegetative parts through increased rate of photosynthesis. This may also be attributed to the lower growth and yield in summer over the *kharif* seasons.

5.2. Plant growth characters

The irrigation layouts had a significant effect on the different growth components. However, the growth components were not influenced significantly by spraying of different nutrients and growth hormone combinations. This is because the spraying was scheduled only after the crop attained 50 per cent flowering *ie*. 40 DAS and a second spray was given a fortnight later.

5.2.1. Plant height

Plant height is an indicator of growth performance of soybean, which is influenced by management and environmental factors. The various treatments influenced the plant height differentially. Plant height was generally higher under the ridges and furrows, which is attributed to optimum moisture level that was retained in this system.

The foliar treatments supplying mineral nutrients through DAP and KCl registered higher values of plant height over the other treatments. Nitrogen being the chief growth-promoting nutrient, has a tendency to enhance the crop growth. Thus, N containing source used in the treatments *i.e* DAP has increased the plant height substantially compared to control. Another contributing factor in DAP is phosphorus. The P might have improved the nutrient content and uptake, which led to the increased metabolic activities and resulted in quick growth of plants. Similar views were expressed by El Sayed *et al.* (1984) and Subramanian and Dixit (1985). Similarly K also appears to have a favourable influence on plant height in this study as observed by Rajagopal and Velu (1995). However, the influence of foliar application of boron and NAA failed to produce significant impact on plant height.

5.2.2. Leaf Area Index

One of the principal factors influencing canopy net photosynthesis is the leaf area index (Hansen, 1972) which increased rapidly and linearly upto the end of blooming, attaining the maximum in 60 DAS. Thereafter, LAI declined by the abscission of lower leaves. This type of trend was supported by the work of Shibles *et al.* (1975). Also leaf area development aids in the effective interception of light leading to higher dry matter production. Thandapani (1985) pointed out that high leaf area at peak vegetative and peak flowering stages contribute to better yielding ability in pulse crops. For grain legumes, early completion of leaf area development is a pre-requisite to maximise the photosynthetic activity. Higher leaf area attainment before the reproductive phase has been usually associated with higher yields in legumes (Wallis and Byth, 1987).

Thorne (1973) has suggested that delay in leaf senescence may be achieved agronomically through application of N fertiliser at flowering which results in longer retention of the effective photo-assimilatory surface. In the present experiment the effect of DAP on LAI was well expressed and it maintained high LAI even at later stages. Increased LAI with the DAP foliar spray is in agreement with the findings of Upadhyay *et al.* (1988). Higher leaf area resulting from fertilisation of N through DAP is due to intensification of metabolic activity and efficient utilisation of nitrogen (Beringer, 1978). Foliar application of potassium at peak flowering stage increased the LAI of soybean as observed by Rajagopal and Velu, (1995). The enhancement in leaf area due to K has been explained as due to the increase in surface area of the epidermal cells of the leaves (Arneke, 1981). Quing-Yuan (1983) also reported on the formation of functional leaf size in soybean due to K fertilisers.

Foliar spray of boron also increased the LAI due to increased number of leaves and leaf area (Huang, 1979). The large leaf area obtained due to boron spraying is in accordance with the finding of Padma *et al.* (1989). The growth regulator NAA also increased the LAI over control. Similar observation has been made earlier by Sreenivas Reddy and Gopal Singh (1983).

5.2.3. Root length

Root length being an important morphological parameter deserved consideration. Root length was higher in ridges and furrows followed by flat ridges and furrows. The favourable increase in root length under ridges and furrows can be attributed to the well-aerated and friable condition of the soil, better conservation of soil moisture and efficient utilisation of stored soil moisture in this layout. Lack of crusting of soil and evaporation losses which led to loose and porous soil heap aided in better aeration and drainage under ridges and furrows (Michael, 1978; Rangaraj, 1991). Moreover, ridge making increases the infiltration and percolation of water, which restricts impounding of water.

5.2.4. Nodule number

Soybean, being a member of leguminaceae family, derives N from three different sources *ie.*, from soil, from fertilisers and by fixing atmospheric nitrogen through symbiotic association with *Rhizobium sp.* Studies on the nodulation pattern of pulses shows that in general, both the nodule number and dry weight increased upto 45 – 55 days after which they declined (Anthonyraj *et al.*, 1989). The decrease in nodule number with maturity of plants is due to early senescence of the first formed nodule. Patil and Shinde (1980) reported that the decrease in nodule number was more pronounced towards maturity in all varieties of gram. Shanmugam and Sree Rangasamy (1981) also reported maximum number of nodules at pre-flowering stage followed by peak flowering stage with a minimum in the pod initiation stage in green gram. All these results confirm the fact that the demand for N, which is more during the maturity stage is further enhanced due to lack of symbiotic N fixation during this stage.

In the present study, neither the irrigation layouts nor the foliar nutrition had any influence of nodulation, which was evident from the number of effective nodules.

5.2.5. Crop Growth Rate (CGR)

Crop growth rate is related to dry weight gained by a crop in a unit area in a unit time and is a linear function of intercepted irradiance (Shibles and Weber, 1965). Hence maintaining higher LAI has positive effect on dry matter production by increased CGR. The results of the present study indicated that the combined application of boron along with DAP and KCl to be more effective on CGR. The increase in CGR due to foliar spray of these nutrients is attributed to the increased LAI produced by them. The beneficial effects of P application as in the present study are obtained through increased assimilatory apparatus coupled with delay in the fall of CGR resulting into higher dry matter production. The favourable impact of K on LAI and plant height explains the increase in CGR due to K.

5.2.6. Relative Growth Rate (RGR)

Relative growth rate is an approximate measure of net photosynthesis of leaves in a crop community. The RGR increased during early stage and decreased there after as the age advanced. This is due to the decreased competition for moisture and light in the early stages resulting in effective utilisation of resources and greater production of photosynthates. As the age advanced, the competition for these factors would have become intense and there was a reduction in the rate of growth. Similar observation was made by Ojehomon (1970) in cowpea.

The influence of irrigation layouts on RGR was observed at the early growth period. The ridges and furrows and flat ridges and furrows performed equally and better than the flat beds. This is due to the favourable physical condition of the soil and moisture status under these two layouts. The improved plant height, leaf area and root length under these layouts would have culminated in the positive influence on RGR.

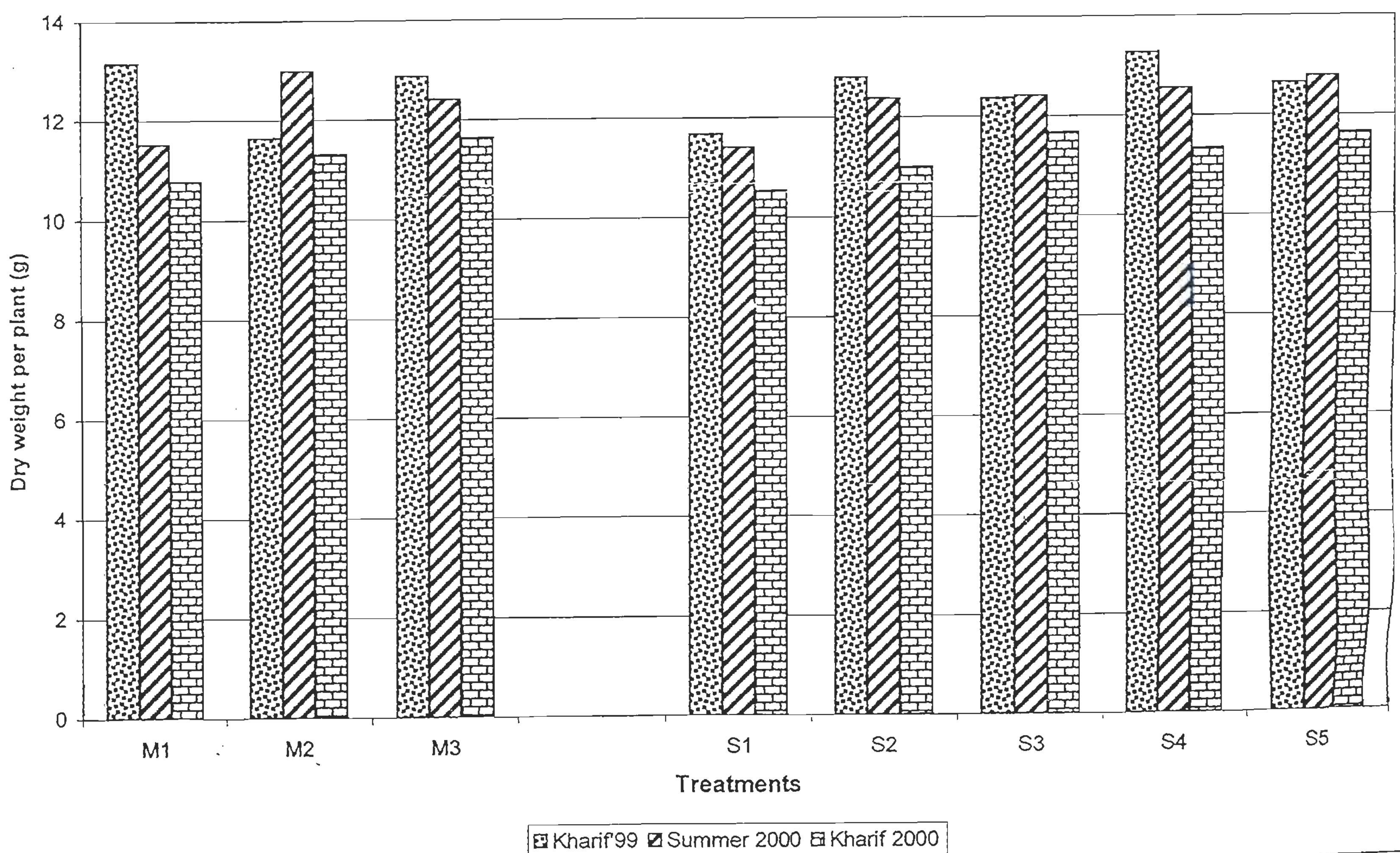
The foliar spray of combinations of DAP, KCl and boron with or without NAA resulted in higher values of RGR followed by the combined application of DAP and KCl. Higher RGR was maintained due to foliar spraying of these different combinations of nutrients at reproductive stage. Since the leaf nitrogen is related with RGR during seed filling period, DAP sprays enable the plant to have higher RGR. Increase in RGR due to DAP application is in confirmation with the finding of Upadhyay *et al.* (1988). The supplementation of DAP with KCl and boron have resulted in further increase in RGR. The favourable effect of boron and NAA on RGR was attributed to the improvement in LAI brought through application of boron (Huang, 1979) and NAA (Sreenivas Reddy and Gopal Singh, 1983).

5.2.7. Total dry weight per plant

The dry weight of plant reflects on the source sink relationship. It depends upon net gain in the processes of anabolism and catabolism of plant. The total dry matter accumulation, the major yield determinant in grain legumes was lower in flat beds as compared to the other two layouts. Ridges and furrows produced higher dry weights both at early and later stages of crop growth. This can be explained by the favourable impact of this layout on plant height, leaf area, root length and growth rates through better aeration, drainage, optimum moisture conditions and lack of soil crusting problems.

Dry weight of plant was also influenced significantly by the different spray combinations (Fig.5). The reduced dry matter in control plants appeared to be due to reduced photosynthetic activity. Considering the foliar spray treatments, DAP and KCl have favourably influenced the growth components. This is attributed to the enhanced photosynthetic rate of the plant, which in turn resulted in increased LAI and DMP (Dashora and Jain, 1994). Thus, late foliar feeding of NPK retarded leaf senescence and

Fig. 5. Effect of irrigation layouts and foliar spraying on dry weight per plant (g)



produced higher total dry weight. Similar results were reported by Posypanov *et al.* (1978); Syverud *et al.* (1980) and Kannan (1986).

Increased total dry weight through increase in leaf surface and also delay in the fall of RGR and CGR as a result of N fertilisation was reported by Upadhyay *et al.* (1988). Buttery (1969) reported the beneficial effect of P fertilisation obtained through increased assimilatory apparatus which also delays the falling CGR and RGR resulting in higher dry matter production. Moreover, inorganic P is very essential for energy transformation process involving ATP and ADP during photosynthesis (Noggle and Fritz, 1992). Hence, the increased uptake of P is responsible for increased rate of photosynthates resulting in higher dry matter production.

In the present study, foliar application of K enhanced the total dry weight of plant, which is in confirmation with the work of Chandrababu *et al.* (1985). The favourable influence of K on dry matter production is further confirmed from the observations made by Gomathi (1996), Sadasivam *et al.* (1990) and Elamathi (1997). The dry weight was found to be higher due to supplementation of DAP and KCl with boron which is due to general increase in vegetative growth due to boron (Padma *et al.*, 1989). The combination including NAA also favoured the dry weight. NAA being a growth stimulant, in terms of cell elongation might have resulted in such an impact (Sarmah and Dey, 1986).

5.3. Physiological parameters

Physiological parameters like relative leaf water content, leaf temperature, stomatal diffusive resistance and transpiration rate are highly responsible to obtain increased yield in irrigated soybean and hence it needs investigation. Higher values of RLWC and lower values of canopy temperature and stomatal diffusive resistance were observed during *kharif* compared to summer planted soybean. This is due to lower day temperature, higher atmospheric humidity and lower evaporative demand during the growing season which resulted in the maintenance of favourable plant water relations.

Environmental conditions during *kharif* season was conducive for greater absorption of water to meet the water demands, whereas summer was not that conducive as such, lacked behind the transpiration need exhibiting higher leaf water potentials. Favourable leaf water potential under adequate moisture supply during *kharif* was due to luxuriant and unhindered absorption of water by crops which led to higher transpiration which in turn lowered the canopy temperature. Higher canopy temperature during summer could be attributed to the greater closure of stomata and higher leaf water potentials (Frank *et al.*, 1974). The differences in plant water and temperature were reflected in lower production of total dry matter and seed yield (Jung and Scott, 1980).

5.3.1. Relative leaf water content

In general, higher values of RLWC were observed in *kharif* than in summer, which is due to the higher relative humidity and better moisture availability status of soil during the monsoon. Among the irrigation layouts, the values of RLWC were higher under ridges and furrows and flat ridges and furrows which might be due to optimum moisture availability in the root zone in these layouts as compared to flat beds. The RLWC values obtained as a result of foliar nutrition indicated the favourable influence of potassium in maintaining higher tissue water potential. Lugg and Sinclair (1979) considered potassium to be a better osmoticum for stomatal regulation and for the maintenance of better internal water balance in tissues. Achitov (1961) suggested that potassium supply increased water uptake and further improved water use efficiency as evident from the values of RLWC in the present study. Jayapaul *et al.* (1995) observed that with the application of K, the reduction in transpirational loss of water led to conservation of considerable quantity of soil moisture with which RLWC could be maintained at higher level for an extended period of time.

5.3.2. Leaf temperature

Lower leaf temperature was noticed in ridges and furrows and flat ridges and furrows and higher temperature in flat beds. The reduction in leaf temperature might be due to higher available soil moisture, which led to higher RLWC in leaves and this might also be the reason for reduction in leaf temperature. The foliar application of potassium registered lower leaf temperature, which is explained due to increased uptake of water and higher tissue turgidity. Thus, all the foliar treatments including K reduced the leaf temperature compared to DAP and water spray. According to Ehler (1973), potassium was found to be a good indicator of stress and potassium applied plants have maintained lower canopy temperature.

5.3.3. Stomatal diffusive resistance

The different layouts failed to influence the stomatal diffusive resistance. The treatments receiving foliar application of potassium either alone or in combination with boron or NAA registered higher values of SDR. This is attributed to the fact that K influences the water economy and crop growth through its effects on water uptake, root growth, maintenance of turgor, transpiration and stomatal behaviour (Nelson, 1981).

5.3.4.Transpiration rate

Ridges and furrows registered higher rate of transpiration due to higher moisture status in this layout. The transpiration rate was reduced in KCl sprayed plots either alone or in combination with boron and NAA, which is attributed to increased stomatal resistance. With the application of K, the reduction in transpirational loss of water can lead to conservation of considerable quantity of soil moisture (Jayapaul *et al.*,1995).

5.4. Yield components

The analysis of yield components helps for a better understanding of the physiological basis of the yield differences caused by different treatments on number of pods per plant, number of seeds per pod, test weight and biological yield. The forth-coming discussion highlights the impact of irrigation layouts coupled with foliar nutrition on various yield components.

5.4.1. Number of pods per plant

As pod number is considered to be the major yield determinant in pulses, counts of pods were made to assess the ultimate yield in the present investigation. The number of pods remained unaltered under various irrigation layouts. Among the sink components, the number of pods per plant was altered more as a result of foliar treatments. Highest number of pods was obtained as a result of foliar spray of a combination of DAP, KCl and boron with or without NAA. Also, addition of KCl and DAP proved their significance during pod formation through increase in pod number over the water spray treatment. The data thus illustrate the importance of N nutrition for soybean plant during reproductive stage, which was earlier reported by Lathwell and Evans (1951) and Mann and Jaworski (1970). Foliar feeding of N through DAP was able to increase the pod number in this experiment as observed by Brevedan *et al.* (1978).

The increase in number of pods could also be due to adequate supply of P, which resulted in growth parameters, particularly LAI with the ultimate increase in the photosynthates produced and favourable dry matter partitioning leading to the formation of more pods (sink). Increased number of pods per plant, following the application of phosphorus was reported by Lauer and Blevins (1989). The increased pod set due to K fertilisation is in agreement with the findings of Seetharani (1990) in blackgram. The highest number of pods achieved by foliar application of boron and NAA along with DAP and KCl stresses the importance of boron application in increasing the pod set. This may be attributed to the fact that boron increases the plasticity of cell walls of floral parts thus decreasing pod abortion. Boron injected directly into soybean plants was found to increase the pod number on the lateral branches and hence yield (Gary Gascho, 1994). Similar influence of boron on pod set, was reported by Garg *et al.* (1999) and Patra (1998). Further, the favourable influence of K in combination with boron brought out in the study was confirmed by Wu Wen Yi (1999). He reported that podding is strongly influenced by soil K and B availability and a shortage of either would reduce pod formation. The increased pod set attained due to the application of the nutrients and NAA in this study is attributed to the increased source activity at pod development stage which could supply required assimilates for pod development.

5.4.2. Total number of seeds per pod (Table 29)

The total number of seeds per pod was not influenced by the alteration of irrigation layouts, except in *kharif* 2000, where ridges and furrows recorded higher number of pods. However, the effect of foliar nutrition was observed in all the three seasons. The combined foliar application of DAP, KCl and boron with or without NAA resulted in higher number of seeds per pod. It is probable that the application of these minerals and growth regulator might have induced large number of new sinks leading to the greater activity of carboxylating enzymes and rate of protein synthesis. This might have resulted in higher photosynthetic rate, translocation and accumulation of metabolites in the sink and eventually greater seed production per unit area. These results are in agreement with the findings of Chaplot *et al.* (1992). The direct supply of K through foliage might have increased the formation of carbohydrates and enhanced the enzyme activity and translocation of synthates resulting in the production of more pods per plant, seeds per pod, test weight and seed yield. The results are in accordance with the findings of Sadasivam *et al.* (1990) who observed that plants fed with K through foliage were found to be more efficient in mobilising the assimilates to the sink in greengram.

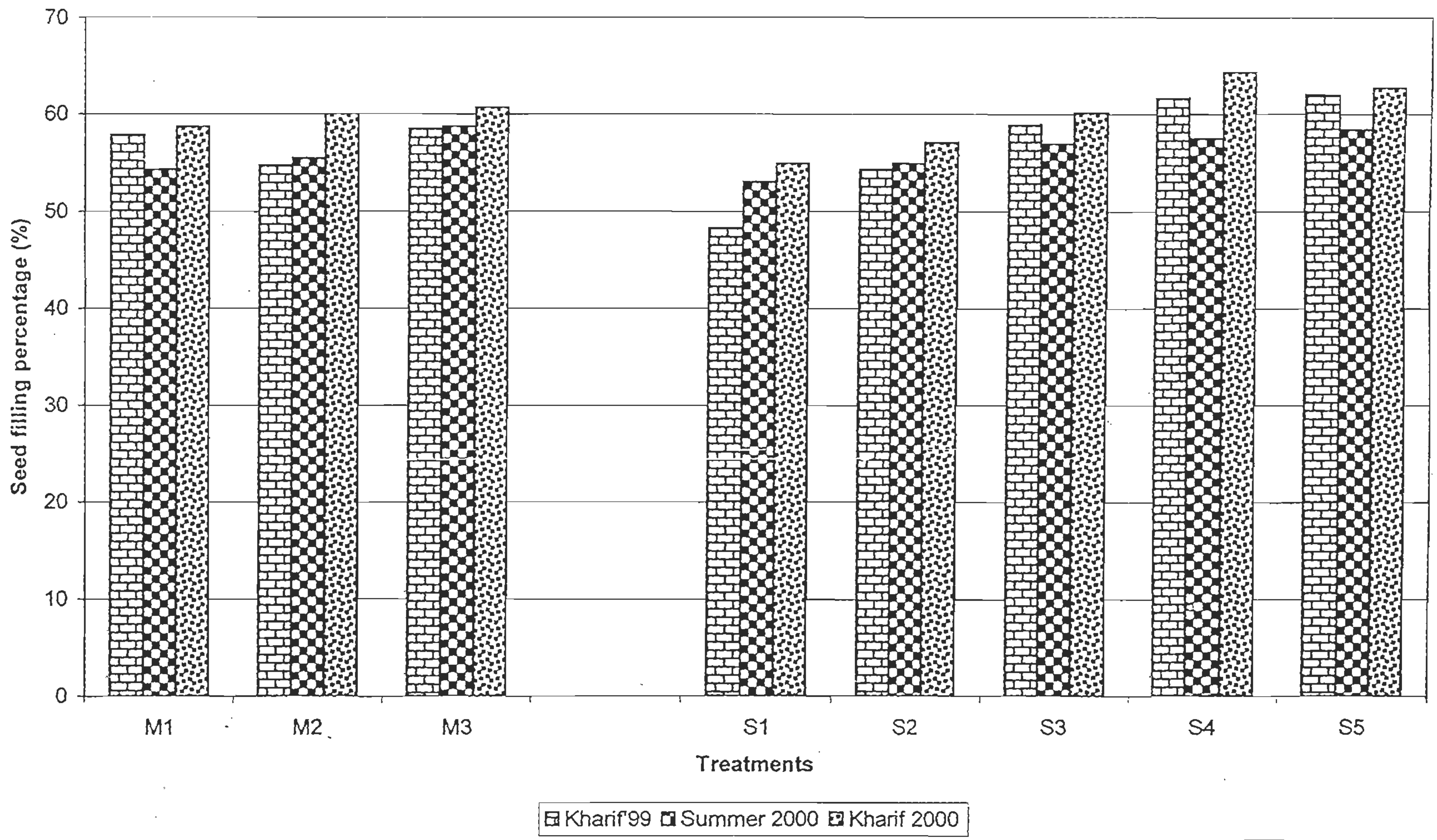
5.4.3. Number of filled seeds per pod and seed filling percentage (Table 30 and 31)

The grain filling period, which is the major determinant of crop yields (Asana, 975; Dewit *et al.*, 1977) was lengthened by the treatments. The higher number of filled seeds under ridges and furrows is attributed to the maintenance of optimum moisture condition through out the reproductive stage under this layout. The higher yield noticed in treatments receiving foliar nutrition may probably be due to the favourable influence on seed filling (Fig.6). Highest number of filled seeds per pod was observed with the combined application of DAP, KCl and boron either with or without NAA. Minerals and plant growth regulators are required for normal seed coat development (Nooden *et al.*, 1985). Garcia and Hanway (1976) found that foliar application of solutions containing N, P and K could apparently supplement the transfer of N, P and K from leaves during senescence in soybean. They speculated that, this supplementation allowed the leaves to continue to function photo-synthetically and they are able to fix more carbon leading to the filling of normally unharvestable seeds. The sufficient nutrients provided through DAP and KCl, which met the nutrient demand of the growing seed resulted in increased sink strength and vascular capacity. This could be expected to enhance seed filling and might have increased seed yield. This is in accordance with the views of Qifuma *et al.* (1998).

5.4.4. Test weight

The influence of irrigation layouts on test weight was not significant. However, the effect of foliar nutrition was seen. Higher values of test weight were obtained with the combination of DAP, KCl and boron with or without NAA. The beneficial role of foliar nutrition of P in enabling the better translocation of photo-synthates to seeds in pulses has been well established. (El-Khawaga and Zeiton, 1986; Velu and Srinivasan, 1984). The data further showed that water sprayed plants recorded lesser test weight. Probable cause

Fig.6. Effect of irrigation layouts and foliar spraying on seed filling percentage (%)

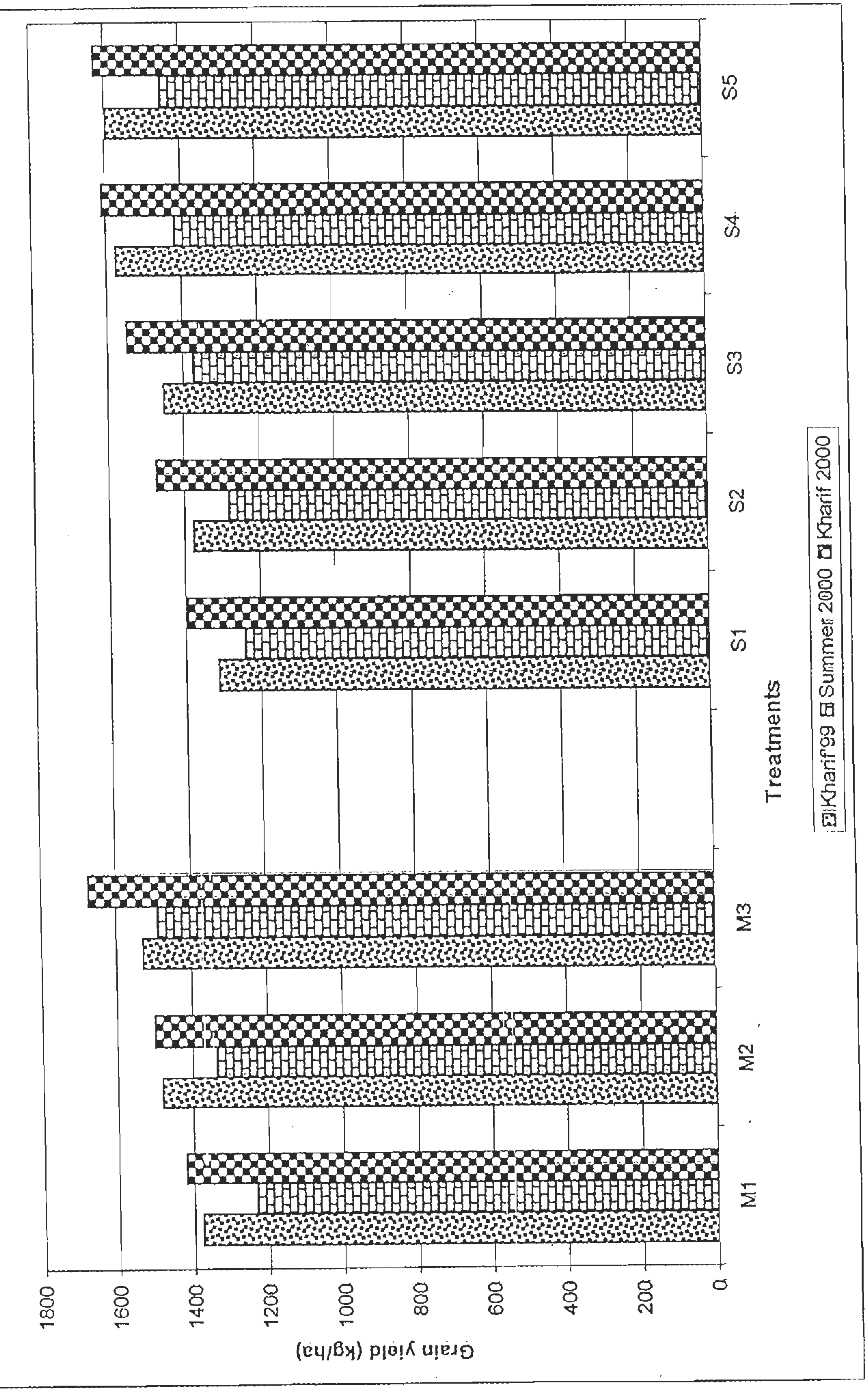


for the reduction is that the flux of mineral nutrients from the roots normally declines during pod filling (Nooden *et al.*, 1989). Thus an exogenous source of NPK along with boron and NAA is obligatory for increasing the seed weight to an effective level. This could be achieved by the delayed leaf senescence and improved photo-synthate and N availability to the seed. The positive effect of foliar feeding of N on test weight is confirmed with the work of Mitra *et al.* (1987). Also the improvement in biomass accumulation due to mineral nutrition during grain filling period increased the source activity and thereby resulted in a favourable seed weight.

5.5. Grain Yield

Grain yield of soybean was influenced to a significant extent by both irrigation layouts and foliar nutrition (Fig.7). The superiority in grain yield under ridges and furrows is due to better aeration and uptake of nutrients. The yield increase under ridges and furrows is due to favourable and optimum availability of soil moisture with uniform flow of water, lesser weed competition because of lesser area of wetted periphery and enhanced yield attributes. These results were in confirmity with the findings of Rajagopal *et al.* (1995). Significant increase in grain yield due to sowing on ridges was in accordance to the results of Mehar Singh *et al.* (1986). The reduced contact area of water on land surface which reduced the soil crusting and evaporation losses are perhaps the reasons for superiority of ridges and furrows over other layouts (Michael, 1978). The favourable influence of ridges and furrows on yield of pulse crops has been reported by Lawand *et al.* (1993); Singh *et al.* (1998); Okada *et al.* (1991). They observed that ridge making loosened soil, increased infiltration and percolation of water and restricted water

Fig. 7. Effect of irrigation layouts and foliar spraying on grain yield (kg/ha)



impounding in field. The supremacy of ridges and furrows over the flat beds was observed since this system allowed water to flow only at the root zone and ensured the maximum moisture availability through maintaining field at optimum soil moisture conditions.

The foliar nutrition with the combination of DAP, KCl and boron with and without NAA produced higher and comparable grain yields. The influence of DAP and KCl was also evident from the data. Highest grain yield recorded under ridges and furrows along with foliar application of DAP, KCl, boron and NAA is due to proper allocation of assimilates to satisfy the potential sink capacity resulting from more amount of moisture and nutrients. Significant response of soybean to foliar application of nutrients might be due to maximum uptake of minerals at early flowering and better nutrient balance in the plants by supplementing nutrients through foliage, leading to increased yield components. The results are in good agreement to those reported by Ingle *et al.* (1999). Improvement in grain yield as a result of foliar nutrition was due to prolonged pod formation and grain filling period and delayed senescence of leaves (Vasilas *et al.*, 1980). The increment in the yield due to foliar spraying with P may be attributed to the activation of the metabolic processes and by the abundant presence of P in leaf tissues, where its role in building of phospholipids and nucleic acids is well known.

Another reason attributed was that foliar feeding of nutrients could avoid the depletion of the nutrients in the leaves and thus aid in translocation of the elements from the leaves to the developing pods. This also avoids the resulting reduction in photosynthetic rate during such period due to poor nutrient uptake from the soil (Garcia and Hanway, 1976). Further, as evidenced in this study the synergistic effect of K in combination with boron has been reported by Wu Wen Yi (1999) in soybean and Sakal *et al.* (1988) in black gram. Also, the favourable influence of application of nitrogen in combination with boron has been observed from the present data as also evidenced from the findings of Gary Gascho (1994). The yield increase due to addition of NAA is attributed to the reduction in flower drop possibly due to metabolic activities stimulated by NAA (Deotale *et al.*, 1998). The positive interaction of exogenously applied hormone with the endogenous one (synergistic effect) which in turn favourably affected the physiological processes also explains the yield increase due to NAA (Patel and Saxena, 1994).

The foliar nutrition also aided in achieving higher harvest index. The increase in harvest index could be due to proper development of reproductive parts. The increased nutrient availability at maturity stage must have improved the mobilisation and translocation of photo-synthates to seeds and aided in better grain filling as stated by Sambasiva Reddy and Saxena (1982).

5.6. Seed quality

The quality of the produce assumes significance when productivity is increased. If the quality parameters are improved by the treatments it will be of immense practical value in soya industry. Seed quality was not influenced by the different irrigation layouts. However, seed protein content was significantly influenced by the foliar combinations including DAP and all these combinations were on par with each other which indicates the lack of effect of supplementation of KCl, boron and NAA with DAP. Seed protein content was found to be increased by the application of nitrogen. The present finding is in line with that of Mercadopineda *et al.* (1988). In this aspect, supplementation of N meets the required amount of N to the seeds thereby increasing the protein content as found in the case of treatments receiving DAP. In addition to P, DAP aids in better utilisation of N for protein synthesis. Foliar spraying of K, boron and NAA could not increase the protein content, which is line with the findings of Kalarani (1991).

Data on oil content indicated that oil content was not influenced by application of DAP alone. The combination of DAP, KCl and boron produced significantly higher and comparable values of oil content over DAP and water spray treatments. Enhanced uptake of P and K through foliar spray of DAP and KCl might have increased their concentration in the plant and aided in photosynthesis, accelerated nutrient uptake and subsequent translocation to sink into oil. This corroborates with the findings of Rajamohan and Moosasheriff (1991). The supremacy of K established in increasing the oil content is in confirmation with report of Massay (1973). Boron was also found to be effective in increasing the oil content, which is confirmed by the work of Chandel *et al.* (1989), but NAA had no effect on oil content.

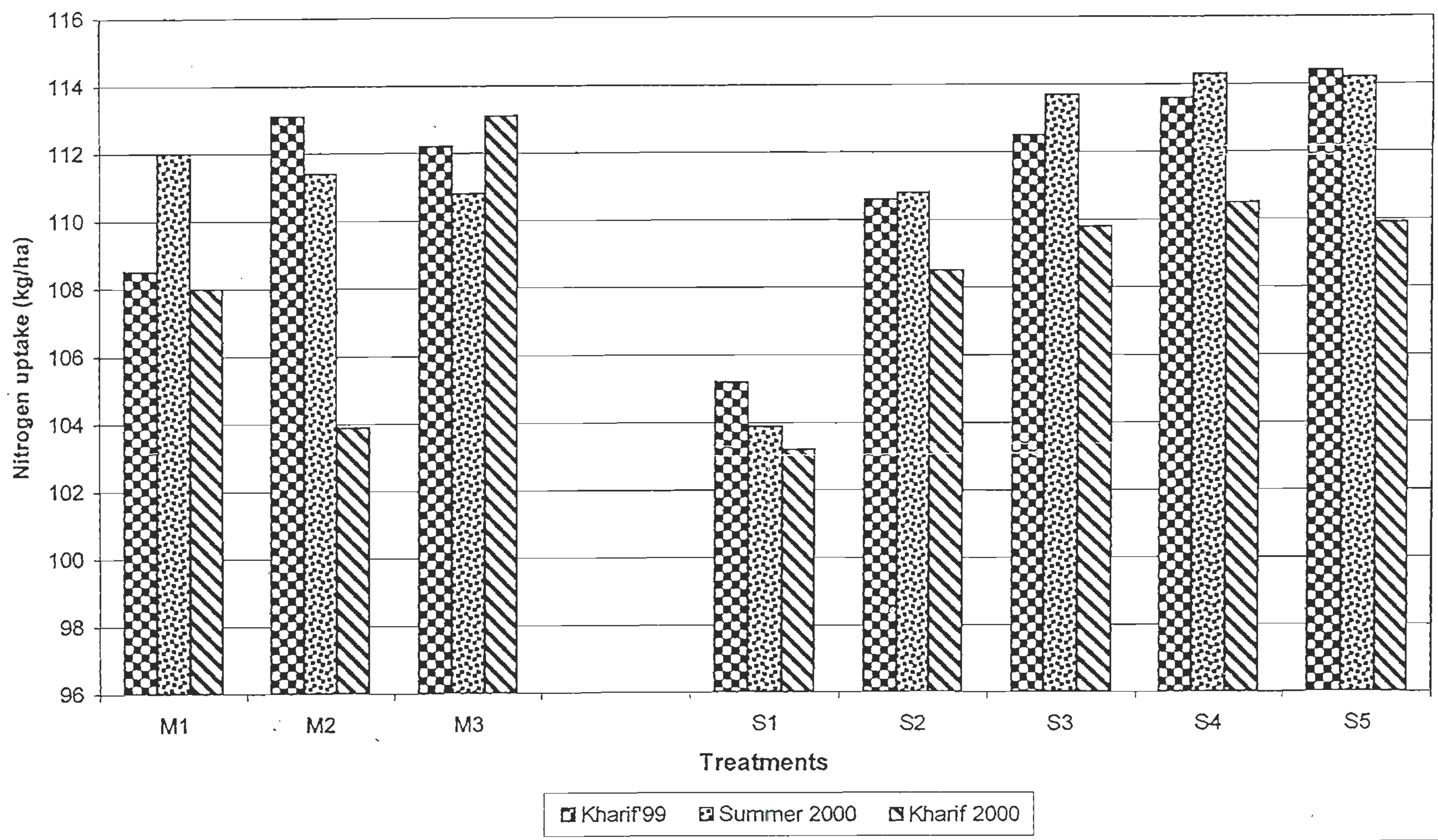
5.7. Nutrient Uptake

The result obtained substantiate the hypothesis that nutrient uptake from the soil is not adequate to supply the needs of the plant. Depletion of nutrients from leaves caused reduction in nutrient content during seed filling period (Garcia and Hanway, 1976). Though the availability of NPK in the soil is adequate, shortage in the supply of carbohydrates to the roots during the seed filling period, leads to poor uptake of nutrients (Lawn and Brun, 1974). Marschner (1986) reported that generally the levels of minerals in xylem sap and their flux into the shoot decline during the reproductive phase in monocarpic plants.

The irrigation layouts had only little or insignificant effect on the nutrient uptake (Fig. 8). The yield of crop is generally mediated through the absorption of nutrients, which is reflected in the nutrient concentration in different parts of the plant. Improved nutrient uptake might be possible through better plant growth as evidenced from the various growth components. This corroborates with the findings of Singh *et al.* (1995). The foliar spray of nutrients and plant growth hormones enhanced the nutrient uptake, minimised the nutrient depletion of the leaves. Due to this photosynthesis in the leaves is maintained at a higher level resulting in increased yield. Similar observation was made in this experiment also.

Foliar spray of DAP, KCl and boron had a highly significant effect on nitrogen uptake. Foliar feeding of DAP resulted in increased content of N throughout the crop growth period. The beneficial effect of foliar feeding of DAP could be due to the supply of an alternative source of N for the plants which could show only poor absorption of N through the root system (Manian *et al.*, 1987). Increased uptake of nutrients due to P fertilisation has been supported by the work done by Nimie and Jagdisseth (1988). Also the contribution of N through biological nitrogen fixation was found to be poor during the

Fig.8 Effect of irrigation layouts and foliar spraying on nitrogen uptake (kg/ha)



reproductive stage (Sahul Hameed *et al.*, 1986) and hence the external supply of nutrients during the reproductive stage becomes imperative.

The uptake of P and K were also influenced both at flowering and maturity stages of crop growth by the foliar spraying of nutrients. The increased content of P and K due to foliar spray of nutrients observed in this experiment, may be due to the direct supply of nutrients to the foliage and the synergistic effect of nutrients on the uptake of N, P and K. From the findings of Rayar (1983) it is observed that K could increase the P uptake also. Higher amount of N, P and K uptake through foliar application of boron found in this experiment is in accordance with the work of Schon (1980).

5.8. Water use and Water use efficiency

The higher seasonal total water consumption during summer was due to increase in number of irrigations. The total water consumed during the crop period is mainly dependent on the amount of effective rainfall received during the crop period. The effective rainfall recorded during summer was only 70 mm as against 169 mm and 308 mm during *kharif*, 99 and 2000 respectively. It is also decided by the prevailing moisture condition of the soil and the increased evaporative demand caused by atmospheric parameters. The high evaporative demand of the atmosphere could be attributed to the higher mean solar radiation received in summer.

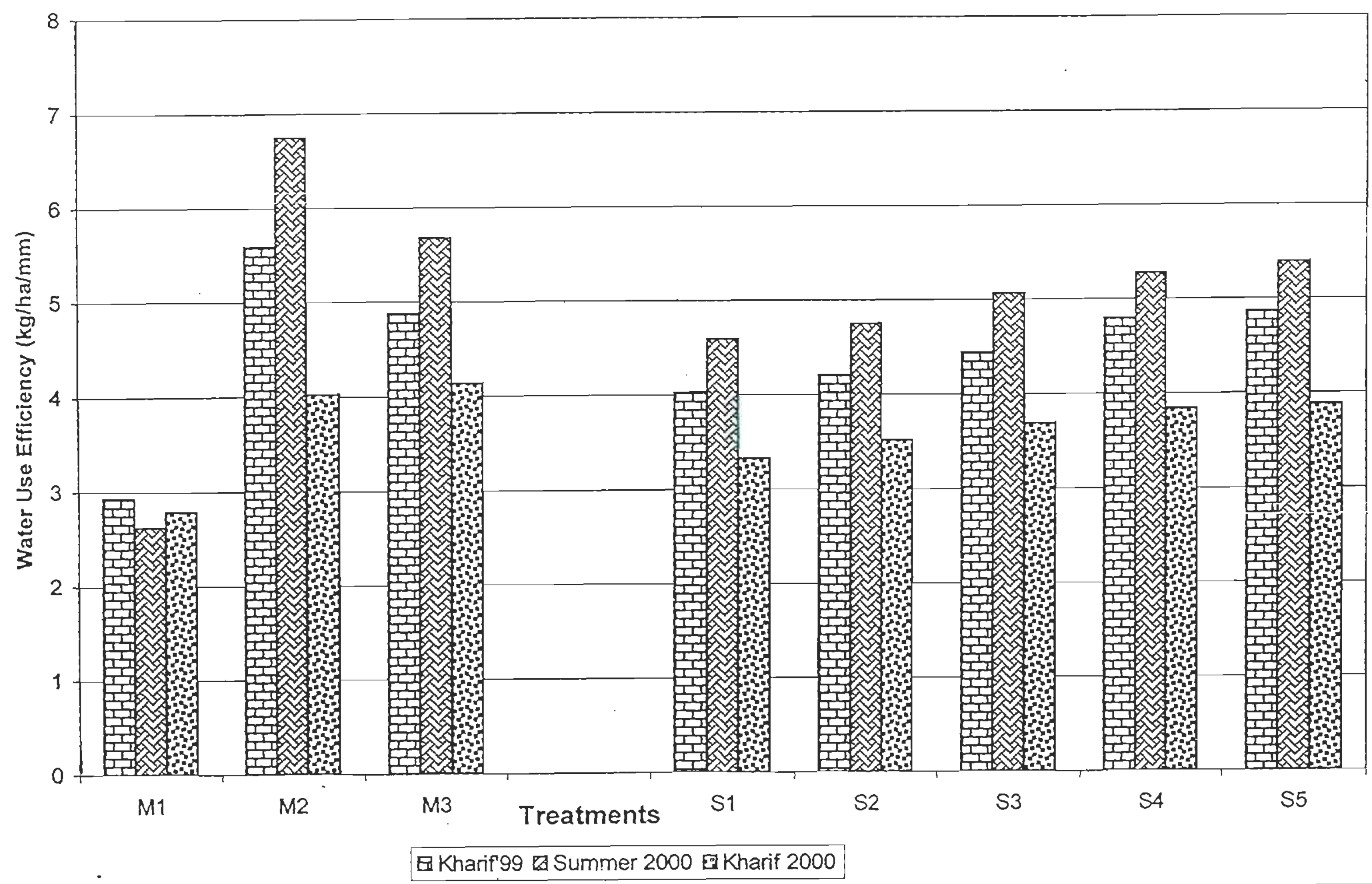
Both flat ridges and furrows and ridges and furrows recorded mean WUE of 54.6 and 49.0 kg ha^{-1} cm^{-1} respectively, while the flat beds recorded only 27.8 kg ha^{-1} cm^{-1}. Higher WUE in flat ridges and furrows was due to consumption of less quantity of water than other irrigation layouts (Fig.9). This is in line with the results of Rasve *et al.* (1983), who reported that groundnut grown on ridges and furrows, was found to be more efficient in utilising irrigation water as compared to flat beds. The flat beds registered lower WUE not only due to utilisation of higher quantity of water but also due to lack of corresponding yield increase. The maximum WUE under limited irrigation was observed by Khade *et al.* (1989). Similar findings were also reported by Bharambe *et al.* (1999); Sharma (1996); Meyyazhagan (1996) and Patel *et al.* (1995).

Among the spray combinations, inclusion of KCl registered higher water use efficiency. Many factors can be attributed to be the favourable impact of K on crop water relations. K is considered to be a better osmoticum, which favours maintenance of internal water balance, cell turgidity, inducing drought tolerance and helping in transport of carbohydrates (Lugg and Sinclair, 1979). Achitov (1961) suggested that K increased water uptake and improved water use efficiency. The favourable influence of K on water economy was reported by Nelson (1981).

5.9. Post harvest soil nutrient status

Generally, growing legumes helps in nodulation and ultimately enriching the soil available N status (Das and Mathur, 1990). Higher amount of post harvest soil N recorded as compared to initial status could primarily be attributed to the effect of higher number of functional root nodules which could have fixed more N from atmosphere and supplied to the plants. Further, disintegration of root nodules at later stage might have

Fig.9. Effect of irrigation layouts and foliar spraying on Water Use Efficiency(kg/ha/mm)



also added more N to the soil. Enhancement of post harvest soil available N due to disintegration of root nodules was earlier reported by Thakur and Panwar (1995).

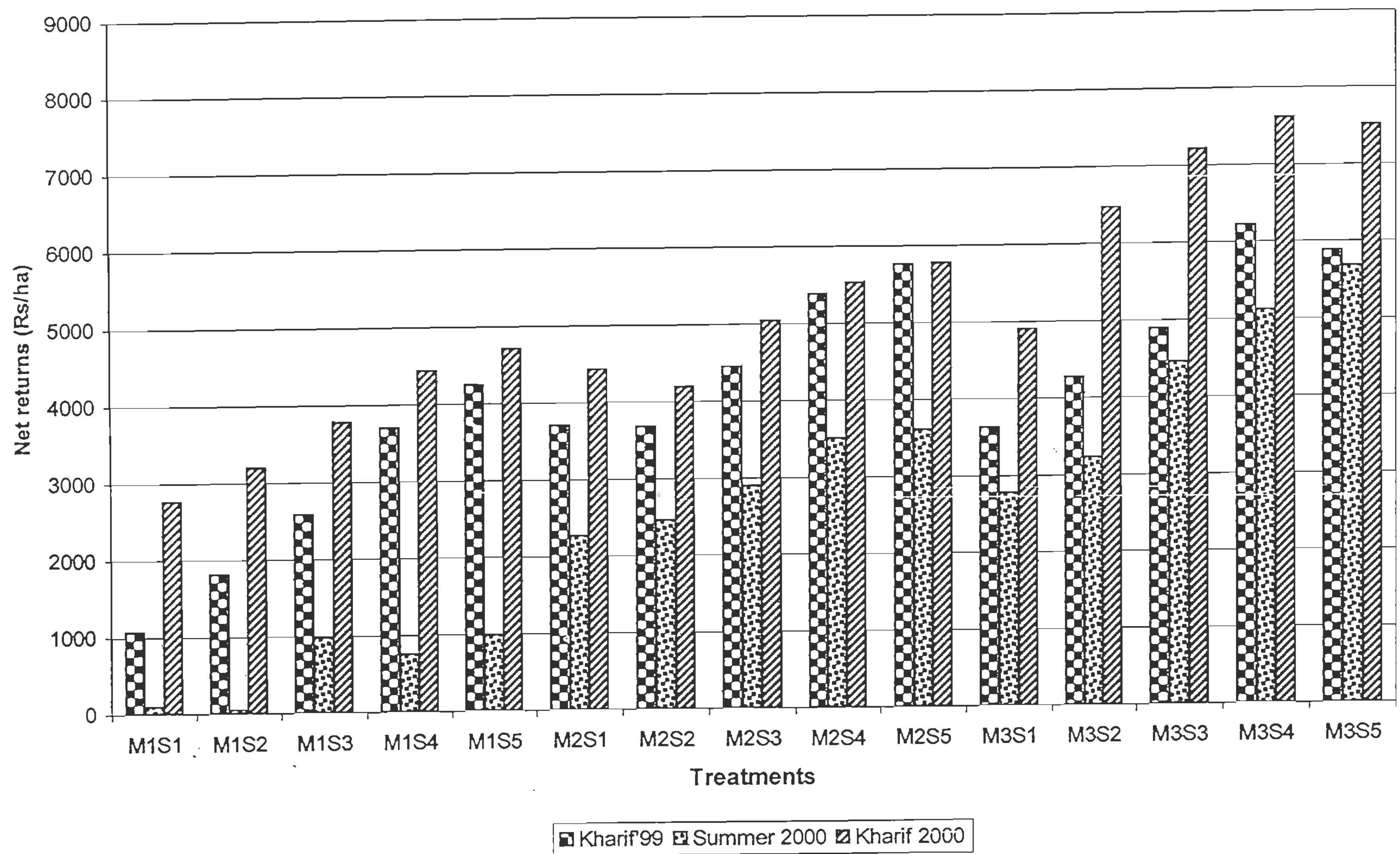
The leaf fall is yet another factor, which contributed to the enrichment of nutrient status in the soil. Foliar application of nutrients, which resulted in better nutrient uptake, correspondingly reflected on the increased addition of nutrients to soil through leaf fall. From the data, it is evident, that post harvest soil nutrient status was higher in plots which received DAP and KCl under various nutrient combinations.

5.10. Economics

The economics varied according to the adoption of different irrigation layouts (Fig.10). Though the cost incurred for ridge making was higher under ridges and furrows and flat bed and furrows as compared to flat beds, due to lesser water used in these layouts, the total cost of cultivation remained lower than the flat beds. Water being a priced commodity, through increased amount of water used under flat beds the cost of cultivation was also higher, more so during summer. Through higher economic yields obtained under ridges and furrows, the cost involved was well compensated by the increased net returns.

Foliar spraying can be considered as a low-cost technology for pulse crops like soybean since it becomes imperative to achieve higher yields. By combining the different nutrients viz., DAP 2 %, KCl 1%, boron 0.2% and NAA 40 ppm, in a single spray the cost and labour involved for spraying operation is reduced and accounts only for the cost of chemicals included. This combined nutrient spray helped to attain higher yields and

Fig.10. Effect of irrigation layouts and foliar spraying on net returns (Rs/ha)



net returns since all the nutrients essential during the reproductive stage are supplied at a single stroke at no extra cost. The B:C ratio also raised accordingly.

The summer crop registered lower net return especially under flat beds mainly due to the higher cost involved in irrigation. Not only the cost of cultivation is high but also the economic yields are lower in summer which culminated in lower net returns and B:C ratio in summer as compared to kharif season.

SUMMARY AND CONCLUSION

CHAPTER VI

SUMMARY AND CONCLUSION

Cultivation of soybean (*Glycine max* (L.) Merill) is now gaining momentum to meet the acute shortage of edible oil and protein. The yield potential of this wonder legume has many set-backs, the important one being its poor seed filling capacity. An attempt was made to alleviate this through alteration of irrigation layouts and foliar sprays of nutrients and growth regulating hormone. The irrigation layouts included were flat beds, flat ridges and furrows and ridges and furrows. The effect of foliar spray of different combinations of nutrients including DAP 2%, DAP + KCl 1%, DAP + KCl 1% + boron 0.2% and DAP + KCl 1% + boron 0.2% + NAA 40 ppm were studied. The sprays were given over and above the recommended dose of fertilizers (20:80:40 kg NPK ha^{-1}), once at 40 DAS and a second spray a fortnight later. Three soybean crops on these treatments were raised in split plot design with three replications in *kharif*, 99, summer and *kharif*, 2000.

The objective of this study was to evaluate the different irrigation layouts and foliar pray combinations on soybean in terms of growth, yield, water use efficiency and economics. The effect of the treatments on growth attributes, physiological parameters, yield components, yield, seed quality, nutrient uptake, water use, post harvest nutrient status of soil and economics were studied. The salient conclusions and inferences drawn from the results are presented below:

1. The plant growth components viz., plant height, LAI, root length, CGR, RGR and dry weight per plant were higher under ridges and furrows. The foliar spray of combination

of DAP, KCl and boron registered higher values of growth components which was comparable with other nutrient combinations.

2. All the physiological parameters including relative leaf water content, leaf temperature, stomatal diffusive resistance and transpiration rate were favourably influenced by the ridges and furrows sprayed with the combination of DAP and KCl.

3. The yield components viz., number of pods per plant, total number of seeds per pod, number of filled seeds per pod, seed filling percentage and test weight remained unaltered under different irrigation layouts. The foliar spraying of DAP, KCl, boron and NAA recorded higher values of yield components which was comparable with the foliar combination excluding NAA.

4. The grain yield was significantly higher under ridges and furrows followed by flat ridges and furrows. The foliar spray combination of DAP, KCl, boron and NAA recorded higher grain yield closely followed by the combined application of DAP, KCl and boron. The haulm yield and harvest index were however not significantly influenced by the different treatments.

5. The seed quality parameters including seed protein and oil content were not influenced by the different irrigation layouts. Among the spray combinations, the DAP spray registered significantly higher seed protein content. The oil content was higher with the combination of DAP, KCl and boron.

6. The nutrient uptake was significantly influenced only by the spray combination of DAP and KCl.

7. The water consumption was lower under flat ridges and furrows followed by ridges and furrows. The flat beds registered higher values of water consumption. The water use efficiency was higher under flat ridges and furrows and lower with flat beds. Among the foliar sprays, the treatments including KCl recorded higher water use efficiency and highest values under the combination of DAP, KCl, boron and NAA.

8. The post harvest soil nutrient status was improved by the foliar spraying treatments. The combined foliar spray of DAP + KCl registered higher values of soil available NPK as compared to control.

9. Among the irrigation layouts, ridges and furrows was found more economic and the spray combination of DAP, KCl, boron and NAA was superior in terms of net returns. Ridges and furrows sprayed with DAP, KCl and boron registered higher values of net returns and B:C ratio followed by the combination of DAP, KCl, boron and NAA under the same layout.

In general, kharif crops performed better when compared to summer-sown crop with respect to growth parameters and yield. The water consumption was also higher in summer, which resulted in lower economic returns as compared to the kharif crops.

From the study it can be concluded that raising soybean under ridges and furrows is the best option considering the yield and net returns. However under water constraint condition flat ridges and furrows can be opted considering the water use and water use efficiency. Foliar spraying of DAP 2 %, KCl 1 %, boron 0.2 % and NAA 40 ppm is the best combination in terms of grain yield and net returns.

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* Originals not seen

PLATES

Plate No.1. General view of the experimental field

Plate No.2. Experiment details

Plate No.3. Irrigation layouts

Beds and channels

Flat ridges and furrows

Ridges and furrows

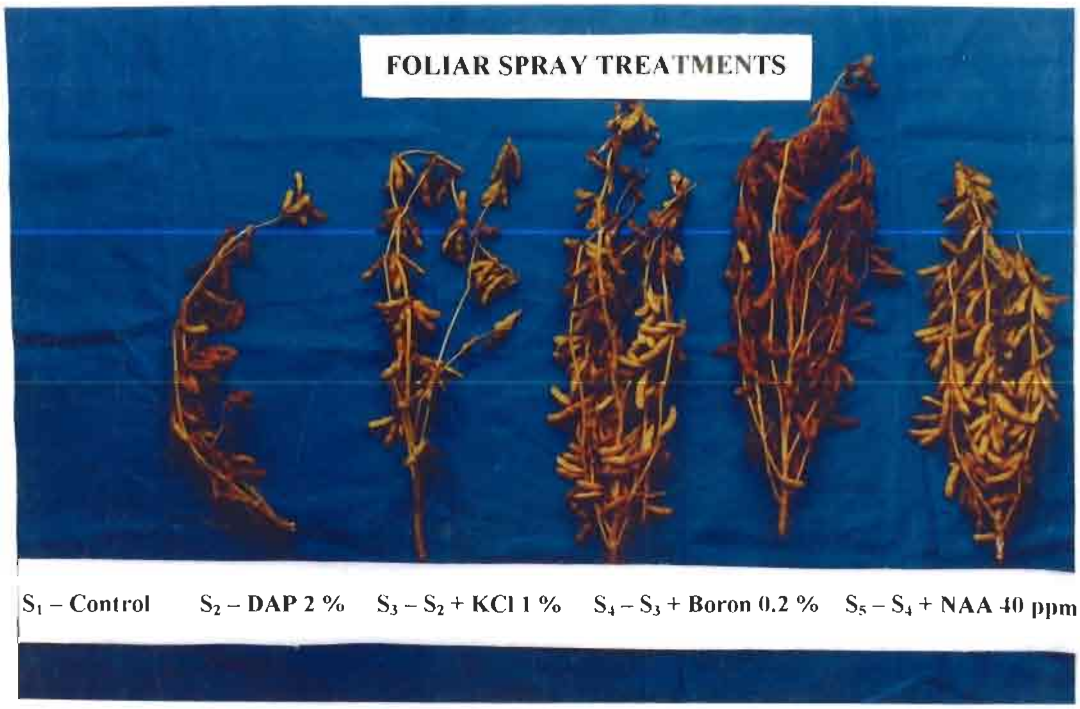

Plate No.4. Foliar spray treatments

Plate No.5. Irrigation module installed in the field channel