

**PHYSIOLOGY OF FOLIAR NUTRITION OF
GROUNDNUT (*Arachis hypogaea* L.) UNDER
DROUGHT STRESS**



By

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**THESIS SUBMITTED TO THE
ACHARYA N G RANGA AGRICULTURAL UNIVERSITY
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FOR THE AWARD OF THE DEGREE OF
MASTER OF SCIENCE IN AGRICULTURE**



**DEPARTMENT OF PLANT PHYSIOLOGY
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2001**

CERTIFICATE

Ms S Vijaya Lakshmi has satisfactorily prosecuted the course of research and that the thesis entitled "PHYSIOLOGY OF FOLIAR NUTRITION OF GROUNDNUT (*Arachis hypogaea* L.) UNDER DROUGHT STRESS" submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by her for a degree of any university.

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This is to certify that the thesis entitled "PHYSIOLOGY OF FOLIAR NUTRITION OF GROUNDNUT (*Arachis hypogaea* L.) UNDER DROUGHT STRESS" submitted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in Agriculture of Acharya N G Ranga Agricultural University, Hyderabad is a record of the bonafide research work carried out by **Ms S Vijaya Lakshmi** under my guidance and supervision. The subject of the thesis has been approved by the student's advisory committee.

No part of the thesis has been submitted for any degree or diploma. The published part has been fully acknowledged. All the assistance and help received during the course of the investigation have been fully acknowledged by the author of the thesis.



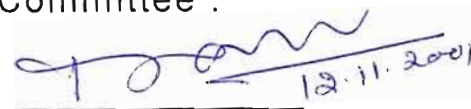
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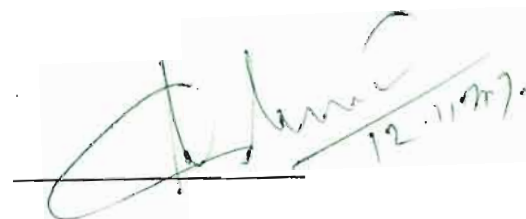
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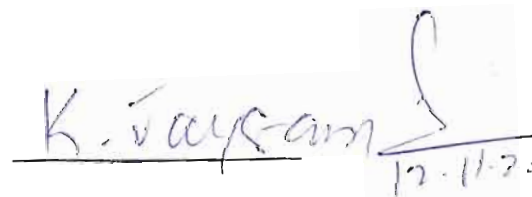
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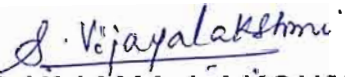
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DECLARATION

I **Ms S Vijaya Lakshmi** hereby declare that the thesis entitled "**PHYSIOLOGY OF FOLIAR NUTRITION OF GROUNDNUT (*Arachis hypogaea* L.) UNDER DROUGHT STRESS**" submitted Acharya N G Ranga Agricultural University for the degree of **Master of Science in Agriculture** in the major field of **Plant Physiology** is the result of original research work done by me. I also declare that any material contained in the thesis has not been published earlier.

Date: 12-11-2001.


(S VIJAYA LAKSHMI)



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ABSTRACT

Name of the Author : **S VIJAYA LAKSHMI**

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A field investigation was carried out on groundnut variety TMV-2 during *rabi* season of 2000 – 2001 on sandy loam soils of Agricultural college Farm, Bapatla to study the effect of foliar nutrition of groundnut under drought stress. The experiment was laid out as Factorial RBD with additional treatment by taking different times of irrigation/no irrigation (irrigation at 30 DAS, irrigation at 55 DAS, No irrigation (drought)) as one factor and different nutrient sprays (Urea (0.5%), Urea (0.5%) + Sugar (0.25%), Urea (0.5%) + Sugar (0.25%) + K₂SO₄ (0.25%), Urea (0.5%) + K₂SO₄ (0.5%) and water spray) as another factor with one control treatment (no irrigation

and no sprayings). All the nutrient sprays were given 10 days before irrigation in irrigated treatments and at 80 DAS in drought treatment.

Foliar spray of nutrients increased leaf area and stem and leaf dry matter accumulation resulting in increased pod yields. Urea (0.5%), Urea (0.5%) + Sugar (0.25%), Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%), Urea (0.5%) + K_2SO_4 (0.5%) spray recorded 7.96, 10.78, 18.6, 17.2% increase in pod yield respectively, over water spray.

The increase in yield with foliar nutrition was due to the fact that the foliar spray supplied proper nutrients for growth and development and increased the dry matter accumulation resulting in increased pod yield. Highest increase in yield was noticed with the foliar spray of Urea + Sugar + K_2SO_4 followed by Urea + K_2SO_4 because they were able to maintain high plant water status and high stomatal resistance besides supplying the major nutrients for the plant under stress conditions.

In drought situations, foliar spray alone at 80 DAS without providing irrigation did not increase the dry matter accumulation and yield of the crop. The reason may be that the

plants might not be able to utilize the nutrients at that final stage of the crop due to lack of water.

Irrigation either at 30 or 55 DAS increased pod yields over drought stress. Between two times of irrigation, irrigation at 55 DAS was found superior to irrigation at 30 DAS i.e. moisture deficit at later part of the groundnut crop decreased the yield when compared with the moisture stress at the early phases of the crop grown. Drought stress resulted in low pod yield when compared with irrigation treatments.

Foliar spray of nutrients and irrigation interaction revealed that the highest increase in yield can be obtained when foliar spray was given at 45 DAS followed by irrigation at 55 DAS because proper requirement of nutrients is met at the pod development stage and seed formation stage. As Urea + Sugar + K_2SO_4 supplied N and K and S and sugar (ready carbohydrate) to the crop, the yield was highest with that spray followed by Urea + K_2SO_4 spray.

Introduction

CHAPTER - I

INTRODUCTION

Groundnut is the most important oilseed crop grown in India and also in Andhra Pradesh. India has an area of 7.5 m. ha with a productivity of 1067 kg ha⁻¹. In Andhra Pradesh groundnut is cultivated in an area of 1.81 m ha. with a productivity of 652 kg ha⁻¹ (Agri India Green Pages, 1999-2001).

Groundnut is a rich source of energy (Calories) because of its high oil and protein content. Groundnut kernels supply about 5.64 k.cal. of energy per gram in the raw form and 5.8 k.cal. in the roasted form. In addition to its high oil (44-56%) and protein (25-34%), it also contains carbohydrates up to 18 per cent and is a good source of minerals and vitamins. Groundnuts are crushed for edible oil and the meal is used for livestock feed. It is also used as seed and for other industrial purposes.

Groundnut crop is grown extensively during *rabi* season in coastal sandy loam soils of Andhra Pradesh in irrigated rice fallows, unirrigated rice fallows and unirrigated upland areas and the crop is sown from December onwards till the end of January. Groundnut being grown under rainfed and

residual moisture conditions is prone to drought stress at one or more of the growth stages with varying intensities and duration (Nageswara Rao *et al.*, 1985). Stress may occur at Growth Stage I (from sowing to 35-37 DAS) or Growth Stage II (35-37 DAS to 60 DAS) or in Growth Stage III (60 DAS to pod maturity) or may occur throughout the total growing period of the crop.

Water deficits affect groundnut growth depending on the stage of crop growth and the degree or intensity of the drought. Drought stress imposed at any of the growth stages curtailed the growth (Anil Grover *et al.*, 2001) and the stress at the flowering being the most inhibitive. Yield was reduced most by drought stress at pod development due to reduced crop reproductive efficiency in groundnut (Golakiya and Patel, 1992).

Drought also causes deterioration in their uptake of nutrients. Soil-moisture deficit decreased N, P and K uptake in groundnut, which varied with cultivars (Polara *et al.*, 1984). Water deficit showed a reduction in nutrient uptake by groundnut plant (Rao *et al.*, 1988). Hence to alleviate the ill effects at the time of treatment of injuries caused by drought, we have take into consideration not only the normalization of plant water regime, but also the normalization of plant feeding and elimination of created deficiencies of some elements. A suitable

way of plant feeding during and after drought is through by foliar nutrition. For this purpose fertilizers are used in the form of diluted aqueous solutions and sprayed over foliage of the plants. As plants cannot derive their nutrition easily under drought conditions from soil, foliar sprays enable the plants to absorb the required nutrients from the solution through their leaf surfaces.

Selvam *et al.*, (1989) observed that foliar application of 2 per cent Urea twice during stress increased pod yield in groundnut. Similarly, post-flowering foliar application of 2 per cent Urea, 0.5 per cent KNO_3 and 0.5 per cent $\text{Ca}(\text{NO}_3)_2$ at 50 per cent flowering and 20 days thereafter increased plant height, leaf area index and yield components such as pods plant^{-1} and test weight in rainfed groundnut (Patra *et al.*, 1995).

The effect of foliar nutrition on resumption of crop growth during drought stress and after recovery from drought stress needs understanding. So, an effort was made in that direction with the following objectives.

1. To study the effect of drought stress at different stages of groundnut.
2. To study the effect of nutrient sprays on the recovery of groundnut from drought stress.

Review of Literature

CHAPTER - II

REVIEW OF LITERATURE

Water can limit the crop growth and productivity virtually anywhere, either because of unexpected dry spells or normally low rainfall. Growth is especially sensitive to water stress and yields can be noticeably decreased even with moderate drought (Renu Khanna Chopra and Sinha, 1998). Foliar spray of nutrients under drought stress conditions may somewhat ameliorate the ill effects of drought stress on growth and yield.

Much research work was done on the effect of drought occurring at different phenophases and the plant responses in relation to its growth, yield and yield components. Good amount of research was also done on foliar nutrition, but its influence under drought conditions was not much attempted. A brief resume of work is herewith presented under relevant headings collected from different studies.

2.1 DROUGHT

Drought stress limits growth through its effect on plant height, leaf area, leaf number and dry matter finally decreasing the yield. It also brings about a change in leaf relative water content, stomatal resistance and canopy

temperature and causes an increase in proline content, which helps the plant in withstanding drought better. Growth parameters like leaf area index, relative growth rate are found to reduce in many plant species under drought stress.

2.1.1 Effect on Growth Characters

2.1.1.1 Plant height

Decrease in plant height with increase in moisture stress was reported by Tamala Reddy (1974) and Subash Babu (1977) in groundnut, Ali and Alam (1973) and Reddy (1983) and Varughese and Irutharaj (1993) in greengram.

2.1.1.2 Number of leaves

Water stress reduced the number of leaves in cotton (Ferreria *et al.*, 1992) Huck *et al.* (1981) reported that leaf number was unaltered due to moisture stress but the leaf area index drastically decreased in soybean.

2.1.1.3 Leaf area

Under rainfed conditions where intermittent drought patterns are common, the ability to retain leaf area during the period of moisture deficit plays an important role in determining productivity. Leaf area is an important factor in carbon assimilation and any change in leaf area will be related to

change in growth rates, relative growth rate as a function of the index and rate of leaf area expansion.

Leaf expansion is very sensitive to moisture stress in corn, soybean and sunflower (Boyer, 1970), in maize (Hsiao *et al.*, 1970 and Acevedo *et al.*, 1971) and in soybean (Sivakumar and Shaw, 1978) and there is a decrease in rate of leaf expansion under drought stress (Begg and Turner, 1976; Takami *et al.*, 1981; Randall and Sinclair, 1988 and Kumar and Elston, 1993).

Fischer and Hagan (1985) concluded that leaf area is very sensitive to water stress and rate of development of leaf area could be used as a plant parameter to evaluate the water status of a crop under field conditions.

Among photosynthesis, transpiration and leaf area expansion the last one was more sensitive to drought (Hoogenboom *et al.*, 1987) and decreasing leaf area is an inevitable consequence of moisture stress reducing transpiring surface and the demand for water (Turner, 1979). Under moisture deficit, crops tend to adjust their transpiring surface area by reducing leaf growth and enhancing senescence of older leaves to balance transpiration demand against reduced water uptake (Hsiao, 1982).

Leaf area decreased continuously with an increase in soil moisture stress in sorghum (Shahid Umar *et al.*, 1993). Water stress reduced leaf area in cotton (Ferreira *et al.*, 1992) and in greengram (Naidu *et al.*, 2001). Even short periods of water stress in vegetative phase can have permanent effect on the final leaf area accumulated by crops (Boyer, 1970; Acevedo *et al.*, 1971 and Ludlow and Ng, 1977).

Water stress decreased leaf area, but after relieving stress at flowering, pegging and pod development stages a sudden increase in leaf area was observed in groundnut (Patel *et al.*, 1983). Leaf area index was drastically reduced under water stress (Huck *et al.*, 1981 and Roller and Pierre, 1973). Reduction in leaf area index was more when the crop was stressed at flowering stage, but effect of water stress on reduction of leaf area index in the later part of the season was less in groundnut (Golakiya and Patel, 1992).

Increasing soil moisture deficit decreased leaf area index at flowering stage (28-49 DAG) by about 48% and 50% in groundnut varieties J-11 and GG-2 respectively, whereas water stress in the later part of the season reduced leaf area index only to a lesser extent that was attributed to the development of extensive root system and hardiness of the crop as it advanced towards reproductive phases of development (Golakiya and

Patel, 1992). High leaf area index and leaf area duration during pod filling stage can result in higher pod yield in groundnut (Ramachandrappa *et al.*, 1993).

Moisture stress was known to reduce the rate of cell division and enlargement (Bidinger, 1978 and Zorica Joranovic, 2001) and reduction in leaf area index was a consequence of reduced rate of cell division and enlargement in groundnut (Ramesh Babu *et al.*, 1984). The decrease in water potential affected water movement into the growing parts of the plant and decreased cell elongation rate (Bradford and Hsiao, 1982). Recently Bacon *et al.* (1998) reported that the decrease in leaf growth was the result of an ABA dependent mechanism resulting in the p^H of xylem sap under drought conditions.

2.1.1.4 Dry matter production

In any given situation production of dry matter is an absolutely pre requisite. It not only signifies photosynthetic ability in a canopy but also signifies other synthetic processes during developmental sequences. The photosynthetic rate of the leaf is seldom as responsive to mild water stress as is leaf expansion (Boyer, 1970). There was a significant decrease in rate of photosynthesis with water deficit in soybean (Planchon *et al.*, 1986). Severe decrease in photosynthesis with water deficit in soybean was also observed by Bladocchi *et al.* (1985).

Water stress at flowering for four days decreased photosynthetic rate in groundnut (Bala Subramanian, 1990). Decrease in photosynthetic rate was due to increased stomatal resistance in groundnut (Pallas *et al.*, 1979).

Decrease in chlorophyll content was observed under water stress conditions (Garg *et al.*, 1998). Water stress also reduced nitrogen fixation (Venkateswarlu *et al.*, 1991) and nitrate reductase activity (Shahid Umar *et al.*, 1991 and Sharma *et al.*, 1990).

Moisture stress was found to decrease the phytomass production and relative growth rate in cotton (Jordan, 1970) and in soybean (Sivakumar and Shaw, 1978). Decrease in relative growth rate with the onset of reproductive phase in groundnut was observed by Venkateswara Rao *et al.* (1986). Decrease in dry matter yield with water stress was observed by Garara and Yadav (1992) in groundnut.

Among different growth stages, flowering period was found to be the critical stage for moisture stress in groundnut variety TMV-2 and progressive reduction in vegetative growth and yield was observed as the soil water stress increased, particularly during flowering (Reddy and Rao, 1968). Reduction in dry weight varies with duration of drought. Reduction in vine

weight was observed with 70-day drought but not with 35-day drought in groundnut (Pallas *et al.*, 1979).

On the whole, moisture stress is known to significantly effect the dry matter production, leaf area and leaf area duration in groundnut (Sastry *et al.*, 1979 and Sabale and Khuspe, 1986). Water stress reduced number of nodules, leaf area and total dry weight and total chlorophyll and protein contents in groundnut (Mohan and Rao, 1989). Decrease in leaf water potential also decreased dry weight, plant height and leaf area of soybean seedlings (Adjei-Twum and Splittstoesser, 1976).

Water stress during flowering and pod development was highly detrimental to the leaf area development, dry matter production, pod formation and yield compared with stress during the vegetative phase. The recovery of growth from stress was better after relief at the vegetative phase than at later growth phases (Ravindra *et al.*, 1990). Naveen *et al.* (1992) on the other hand reported that moisture stress at flowering and pegging reduced the dry matter to a greater extent in groundnut than at any other stages. Ramachandrappa *et al.* (1993) found alleviation of stress at 40 DAS by irrigation caused higher dry matter production and distribution in groundnut.

2.1.1.5 Days to 50% flowering

Flowering is also an important aspect that can be influenced by the moisture stress. Moisture stress in most of the cases was known to delay the days to flowering and decrease the number of flowers in groundnut. Moisture stress early in the season delayed blooming in groundnut (Reddy *et al.*, 1980). Moisture stress during reproductive phase in groundnut increased the days to 50% flowering by 4 – 5 days (Golakiya and Patel, 1992). Water stress also reduced the number of flowers in cotton (Ferreira *et al.*, 1992) and in groundnut (Garara and Yadav, 1992 and Patel *et al.*, 1983).

Water stress may also influence the opening of flowers, but the initiation may be unaltered. So, a sudden variation in the environmental factors like sudden release of water stress can cause the groundnut plant to flower profusely (Williams and Rao, 1981). Thus, though moisture stress decreases number of flowers, rewatering after stress will increase number of flowers in groundnut (Patel *et al.*, 1983). Water deficits during flowering were found to increase the grain yield due to redistribution of assimilates from vegetative to reproductive organs (Turner, 1988).

Temporary adverse effects of stress during early growth stages was buffered by heavy flush of flowers and hence

the pegs in groundnut as the stress terminated (Golakiya and Patel, 1992).

2.1.2 Effect on Physiological Parameters

2.1.2.1 Relative water content

Plant growth is controlled directly by its water status (Kramer, 1963) as plant turgidity is important in relation to the opening and closing of stomata, expansion of leaves and flowers, and movement of water and nutrients to various parts of the plant (Kramer, 1969). Plant water status is measured by the leaf relative water content and relative water content is an important parameter which indicates the ability of a plant to maintain a high leaf water balance during drought stress which can be used as an index to determine drought tolerance.

Water stress decreased relative water content in groundnut (Shahid Umar *et al.*, 1991). Water stress at vegetative phase significantly reduced relative water content (Ravindra *et al.*, 1990). Moisture stress at any of the critical growth stages like tillering, flowering, grain filling and dough stages reduced the relative water content of the leaf (Ravichandram and Mungse, 1997 and Mata and Lamattina, 2001). Decrease in relative water content decreased leaf area of chickpea (Narender Singh *et al.*, 1997). Relative water content was positively correlated with leaf area and genotypes of greengram

which were able to maintain high leaf relative water content and high drought tolerance index showed less reduction in yield under receding soil moisture situations (Naidu *et al.*, 2000). The cultivars of soybean that have the capacity to maintain high plant water status over a wide range of soil moisture conditions were superior in tolerating drought (Frederic *et al.*, 1990). Decrease in relative water content under water stress in cluster bean was found to decrease rate of photosynthesis (Kuhad and Sheoran, 1986). Drought stress decreased number of pods plant⁻¹ and number of seed pod⁻¹ in all genotypes of blackgram. But the genotype which maintained highest leaf area, relative water content, leaf proline content and specific leaf weight showed higher pod number plant⁻¹ and seed number under drought stress (Surya Kumari *et al.*, 2000). In plants relieved from water stress, leaf water potential recovered much faster than nitrogenase activity (Venkateswarlu *et al.*, 1990) .

2.1.2.2 Leaf temperature

When the leaf water potential falls below a critical level, the stomata closes and restricts the water loss. This leads to a loss of the cooling effect of transpiration, finally increasing leaf temperature (Ehrler *et al.*, 1978). So, leaf temperature can be used as an indirect measurement of leaf water status of plant. Canopy temperature was used to estimate plant water

status (Jackson *et al.*, 1981). Canopy air temperature is one of the physiological attributes associated with drought tolerance of wheat cultivars (Blum and Pnuel, 1990).

Water stress increased canopy temperature in dryland groundnut crop (Bala Subramanian *et al.*, 1993). Increasing water stress increased canopy air temperature difference in groundnut (Pandey *et al.*, 1984).

Leaf temperature in stressed rice plants was marginally greater than in their counter parts raised under normal water supply (Tiwari *et al.*, 1998). Complete moisture stress in wheat did not increase leaf temperature at tillering and flowering but increased leaf temperature at grain filling and dough stages (Ravichandram and Mungse, 1997). Photosynthesis was markedly lowered due to increased leaf temperature under water stress at pegging to pod development growth stages of groundnut (Patel and Golakiya *et al.*, 1993). It was also revealed that the finger millet genotypes, which maintained cooler canopy extracted more water from deeper layers than the warmer genotypes and had an advantage by producing higher biomass and grain yield at harvest under stress (Gowda, 1996).

2.1.2.3 Stomatal resistance

Transpiration rate, photosynthesis rate and leaf water potential are affected by the opening and closing of stomata. Under normal conditions transpiration rate is directly proportional to the available soil moisture content and plant growth and inversely proportional to the stomatal resistance (Mata and Lamattina, 2001).

In water stressed plants of groundnut leaf water potential, transpiration rate and photosynthesis rate decline progressively more with increasing period of water stress. When water stress starts to develop, stomatal conductance was more sensitive than the very processes of water loss and CO_2 exchange, which are regulated by it. The decrease in stomatal conductance coupled with the folding of leaves may help the plants to reduce transpiration under water stress and prevent the water loss and the subsequent dehydration of the cells (Bala Subramanian and Maheswari, 1990). Thus the resistance offered by stomata under drought conditions plays an important role in the survival of the crop.

Comparing the dryland and irrigated groundnut, Bala Subramanian *et al.* (1993) found that in dryland grown groundnut stomatal conductance was lowered by 25 per cent. In groundnut, stomatal conductance and photosynthesis rate

declined faster than the transpiration rate (Bala Subramanian *et al.*, 1993 and Bala Subramanian and Maheswari, 1990).

Leaf diffusion resistance increases with the lateness and severeness of drought and much of the plant water stress that developed during drought can be relieved the day after irrigation returning the leaf diffusive resistances to normal. If full season irrigation is not possible in groundnut because of the demands on the system then scheduling irrigation in the later part of the season appear next in importance in groundnut crop (Pallas *et al.*, 1979). In wheat, stomatal resistance increased with time and increase in canopy temperature, but decreased sharply after irrigation and stomatal resistance increased with increase in canopy temperature (Mohan Singh *et al.*, 1993).

2.1.3 Effect on Biochemical Parameter

2.1.3.1 Proline

Proline accumulation is one of the major changes in the nitrogen metabolism of water stressed plants. Proline accumulation increases proportionately faster than other amino acids in plants under water stress. Proline accumulation is proportional to the rate of plant water deficit.

Proline is known to accumulate under water stress conditions and causes for osmotic adjustment (Hsiao, 1973) and

is reported as an index of drought resistance (Singh et al, 1972; Kuhad and Sheoran, 1986 and Cushner and Bohnert, 2000). A tremendous free proline accumulation (100 times the normal) occurs under stress conditions in bermuda grass (Bernett and Naylor, 1966), groundnut (Mehri *et al.*, 1977) and cotton (Mc Michael and Elmore, 1997). Water stress increased proline content in leaves of groundnut crop (Sharma *et al.*, 1990 and Shahid Umar *et al.*, 1991) and in axis of chickpea (Singh and Kumar, 1992). Vinod Goyal (2001) reported that proline content that was increased under drought stress started disappearing in the leaves with simultaneous increase in water potential. Yoshida *et al.* (1997) pointed out that accumulation of proline in dehydrated plants was due to the activation of the biosynthesis of proline and by the deactivation of degradation of proline.

A strong correlation has been reported between proline accumulation in seedlings of barley varieties and stability and yield under different drought conditions (Renu Khanna Chopra and Sinha, 1998). However, Garg *et al.* (1998) reported no correlation between proline accumulation and growth and yield of cluster bean genotypes. High proline and its further accumulation under water stress is known to act as a storage compound for carbon and nitrogen in Bermuda grass (Bernett and Naylor, 1966). More dry matter production in sugarcane

was observed in varieties showing high proline accumulation under water stress conditions and they had greater capacity to withstand drought (Singh and Singh, 1986, Nanjo *et al.*, 1999).

Sharma *et al.* (1989) reported that proline content couldn't be used as an indicator of stress. The soybean plants, which accumulate more proline, are less efficient in utilizing nitrogen on subsequent relief from water stress (Sarkar, 1993).

2.1.4 Effect on Yield and Yield Components

The yield of a plant and a crop depends on the development of yield components (sink) and the availability of assimilates including carbohydrates, minerals and protein etc. and a complementary relationship among them is essential for obtaining yield. If the source is affected when the sink is being established, the size of the sink becomes poor, leading to low yields. Also there is close relationship between the available water in the soil profile in the post anthesis period and yield.

Water deficits during flowering, pod formation and maturity stages reduce the yield of groundnut (Subramanian *et al.*, 1975). A severe reduction in pod yield owing to moisture stress in groundnut has also been reported by Rao *et al.* (1985) and Pathak *et al.*, (1988). But, stress at early stage reduced the sensitivity of groundnut to subsequent drought and can increase

yield due to better distribution of dry matter into reproductive components (Nageswara Rao *et al.*, 1985). Stress at early stages of crop growth was found advantageous as it cut down extra vegetative growth in groundnut (Sridhara *et al.*, 1996).

Flowering and pegging stages of groundnut are considered to be the most sensitive ones to moisture stress by Reddi (1976) and Pathak *et al.* (1986). Adverse effect on pegging was reported by Lee *et al.* (1972), Bhan (1979) and Williams and Rao (1981), whereas pod development was considered to be sensitive to moisture stress by Patel and Padlia (1980) causing high yield losses, because the demand for photosynthetic products would be greater at that phase.

Water stress during flowering and pod development was highly detrimental to pod formation and yield compared with stress at vegetative phase (Ravindra *et al.*, 1990). Pod yields were reduced significantly due to water stress treatments at 50-70 and 70-90 DAS in groundnut (Sridhara *et al.*, 1996). Highest reduction in groundnut yields due to moisture stress was observed during pod filling phase of water stress by Patil and Golakiya (1991) and Stirling and Black (1991).

Water stress imposed during flowering and pegging stages showed greater reduction in groundnut pod yield followed

by water stress at early pod stage, late pod stage and vegetative stages (Naveen *et al.*, 1992). But Garara and Yadav (1992) found that pod development stage alone or in combination with any other stages with water stress was found most sensitive for pod yield and pegging alone or in combination with any other stage was sensitive to haulm yield in groundnut. They also observed that among single cycle, double cycle and triple cycle water stress, water stress at pod development (73-95 DAS), water stress at pod formation and pod development (57-95 DAS) and water stress at pegging, pod formation and pod development (33-95 DAS) reduced the yield to a greater extent respectively compared with its other stages in groundnut.

In cotton moisture stress at flowering stage reduced number of flowers plant⁻¹, number of bolls plant⁻¹ and increased per cent boll abscission finally decreasing seed cotton yield than the stress at vegetative or boll development stage (Ranjinder Kaur and Singh, 1992).

The soil moisture percentage in the feeding zone of around 50-75 cm soil depth is related to pod yields in groundnut (Keese *et al.*, 1975). Moisture stress effects number of pods plant⁻¹ or m², seed number and test weight finally decreasing yields. Moisture stress in general decreased the total number of pods m⁻² and increased 100-kernel weight of groundnut (Rao

et al., 1986). Moisture stress decreased the number of m^{-2} leading to diversion of photosynthates for proper filling of pods resulting in increased 100-kernel weight (Singh and Arora, 1968). Sarma and Siva Kumar (1991) observed that the decrease in pod number plant^{-1} was due to the increase in the stomatal resistance to peg penetration under prolonged drought.

Water stress affected seed formation more than total dry matter yield and harvest index declined as moisture stress increased in grain legumes (Pandey *et al.*, 1984). Seed yield was decreased by moisture stress in bush bean (Rao and Rao, 1997). Water stress decreased seed number pod^{-1} and pod yield in groundnut (Dhopte *et al.*, 1992).

Number of pods m^{-2} was most sensitive to increasing water stress among yield components, due to reduced flower production and greater abortion of flowers. The number of seeds pod^{-1} was less influenced by water stress than the yield and pod number. Seed weight also decreased due to water stress but did not affect the yield much in groundnut (Pandey *et al.*, 1984). Decrease in test weight was considerably reduced with drought stress at pod filling phase (56 DAS to maturity) (Krishna Murthy and Yogeswara Rao, 2000).

2.2 EFFECT OF POTASSIUM NUTRITION UNDER DROUGHT STRESS

It has been well noted, that among various nutrients potassium works efficiently in drought conditions and promotes a number of physiological activities in plants that tend to improve their drought tolerance nature. Potassium activates number of key enzymes and lowers the osmotic potential of root cells and increases the water uptake. It plays a specific role in opening and closing of stomata and checks the transpiration (Evans and Sorger, 1966).

Potassium influences the water economy and crop growth through its effects on water uptake, root growth, maintenance of turgor, transpiration and stomatal regulation (Nelson, 1980). High k^+ status in plants help retain more moisture in leaves during drought period and thus help in reducing the drought stress damage in conifers (Larsen, 1981) and sorghum (Shahid Umar, 1993). Potassium application helped plants in maintaining favourable internal tissue water and metabolic activities under water stress (Vyas *et al.*, 2001).

Potassium helps in better root growth and increases supply of water at the site of energy harvest under stress condition. Adequate potassium nutrition helps in increasing crop tolerance to water stress and promotes root growth that results

in better uptake of nutrients and water in wheat (Polizotto, 1986) and in groundnut (Umar *et al.*, 1990). Potassium being a major nutrient helps for plant growth and development and total dry matter production of the crops to a greater extent (Cadisch *et al.*, 1993). Similarly, stimulating effect of potassium on dry matter accumulation was reported by Sharma *et al.* (1992) in brassica and by Shahid Umar *et al.* (1993) in groundnut.

Soil application of potassium increased plant height, branch number, leaf area index and dry matter accumulation in groundnut (Barik *et al.*, 1994). Different doses of soil-applied potassium increased stomatal resistance under drought stress conditions. Potassium application ameliorated the ill effects of water stress on leaf number, leaf area and dry weight. Application of 20 kg K_2O ha⁻¹ tended to compensate the growth parameters even under severe water stress at all growth stages particularly, at early growth stages and helped the plant in better establishment of groundnut under moisture stress (Shahid Umar and Bansal, 1997).

Potassium application was found to increase the proline content at all levels of water stress in finger millet and groundnut (Krishna Sastry, 1985). Similar findings were reported in groundnut by Shahid Umar *et al.* (1991), who found

that potassium further increases leaf proline content and stomatal resistance under water stress.

Potassium application also increased nitrate reductase activity, relative water content, dry matter accumulation and yield, which would be decreased due to water stress. Potassium application helped in offsetting the decrease in nitrate reductase activity under stress conditions (Khanna Chopra *et al.*, 1980).

2.3 FOLIAR NUTRITION

Under drought stress, plants will not be provided with adequate nutrients as absorption and translocation of nutrients is hampered under moisture stress. In such conditions providing nutrients through foliage may supply the plant its required nutrients.

In dry areas, high evaporative demand and normally very little rainfall limit the carbon and nitrogen availability to the plant, which simultaneously limits biomass accumulation and seed yield. In such cases seed yield can be increased either through carbon or nitrogen input into soybean (Sinclair, 1989).

Foliar application of major nutrients (single salts) such as nitrogen as urea (Barel and Black, 1979) and potassium as K_2SO_4 in soybean (Garcia and Harway, 1976) or KCl in *Beta*

vulgaris (Doman and Geiger, 1979) leads to better growth and yield. Pre-sowing seed hardening for drought tolerance with 1% CaCl_2 or 2% KH_2PO_4 was found effective in groundnut (Arjunan and Srinivasan, 1989). In groundnut Cv. CO 2 s[raying with 0.5% KCl at the onset of seed growth stage showed KCl treatment reduced the effects of water stress at seed growth stage (Mohandass *et al.*, 1989). Foliar spray of diammonium phosphate (2%) at 20 and 30 DAS increased plant height, number of branches plant⁻¹ and also increased number of pods plant⁻¹ and seeds per pod⁻¹ (Srinivasan and Ramaswamy, 1992).

Foliar applied N and P at the critical stages of the groundnut crop were effectively absorbed by the plant and translocated to the developing pods, producing more number of pods and more filling which resulted in higher yield (Thimmegowda, 1983). Foliar application of KNO_3 increased seed yield in *Stylosanthes hamata* (Dwivedi *et al.*, 1998). Sarkar *et al.* (1999) reported that three irrigations at critical stages of the groundnut crop and KNO_3 (0.5%) or KNO_3 (0.25 %) + CaNO_3 (0.203%) @ 800 liters water ha⁻¹ spray at 50% flowering stage increased plant height, leaf area index, dry matter production and also pod yield and yield attributes like number of pods plant⁻¹ and kernel pod⁻¹, however 100- kernel weight was not effected due to spraying. Foliar application of

KNO₃ solution during anthesis period resulted in higher grain yield and straw yield of rice and wheat, due to the effect on the retention of more chlorophyll and delayed senescence by N in KNO₃ and due to the beneficial effect of K on photosynthesis and translocation of photosynthates to sink (Das and Sarkar, 1981).

Bhalaerao *et al.* (1994) reported that three sprays of urea (1.5%) + DAP (0.5%) at 20, 40 and 55 DAS in *kharif* groundnut resulted in increased pod yield due to increase in number of pods plant⁻¹, weight of pods plant⁻¹ and test weight. Selvam *et al.* (1989) reported that foliar spray of 2% urea twice during stress increased the mean filled pods plant⁻¹ and pod yield.

Foliar spray of muriate of potash (2.5%) and urea (2%) at 15, 45 and 75 days after last irrigation before commencement of drought in sugarcane did not increase plant height⁻¹, girth of the stalk and single cane weight, but increased number of millable canes and cane yield in tonnes ha⁻¹. Similarly, in pot culture studies Bharud *et al.* (1986) found that foliar application of urea (2 %) in 40 day old plants and again in summer groundnut increased number of pods plant⁻¹, number of kernels plant⁻¹, but has no significant effect on plant height, total dry matter plant⁻¹ and 100 seed weight.

Foliar spray of ferrous sulphate (0.5%) and urea (2%) @ 700 liters of spray solution ha⁻¹ increased total dry matter production and its accumulation in pods at harvest under late sowing (Patil *et al.*, 1984). Foliar application of urea (2%) + KNO₃ (0.5%) + CaNO₃ (0.5%) at 50 % flowering and 20 days thereafter increased plant height, LAI at 70 and 90 DAS and yield components such as number of pods plant⁻¹ and 100-kernel weight in rainfed groundnut (Patra *et al.*, 1995).

Foliar application of K₂SO₄ at vegetative stage and flower initiation twice on alternate days increased plant height, branches plant⁻¹ and productivity biomass in Indian mustard grown on saline black soils (Gururaja Rao and Yadav, 1997). They also reported marginal increment in specific leaf weight in K treated plants. Seed yield in Sunflower was increased by foliar spraying of urea (1.5%) + diammonium phosphate (0.5%) at 30, 40 and 50 DAS (Sagare *et al.*, 1986). Similarly, sprays of urea (1%) + diammonium phosphate (2%) and K₂SO₄ (2%) reduced senescence in soybean (Kalarani and Jeyakumar, 1998).

Seed yield was increased in bush bean under moisture stress by cobalt nitrate (seed treatment and/or foliar application) (Rao and Rao, 1997). Pod yield was increased by foliar application of K (KCl and K₂SO₄) in groundnut. Foliar

applied K improved crop harvest index and boldness of seed. So, K nutrition as a supplement is beneficial for groundnut crop (Shahid Umar *et al.*, 1999).

Application of K as a spray helped in inducing drought hardiness in the developing cane (Channabasavanna and Setty, 1994).

2.4 EFFECT OF DROUGHT STRESS ON UPTAKE OF NUTRIENTS

Moisture stress may affect the uptake of nutrients because the absorption and translocation of nutrients is hampered. The accumulation of nutrients in the plant may vary either positively or negatively under stress conditions.

Moisture stress at all stages of crop growth reduced the uptake of nutrients by groundnut (Zalawadia and Patel, 1983). Naveen *et al.* (1992) reported that the stress at pre-flowering (11-30 DAS) in groundnut was not associated with the reduction in nutrient uptake, but the stress at flowering and pegging (31-65 DAS) was more injurious to crop growth, followed by the stress at early pod stage (51-70 DAS). Water stress in groundnut increased P, K, Ca and Mg contents in both haulms but N content increased in pods but decreased in haulms (Parmar *et al.*, 1989).

Moisture stress very much affected the uptake of nutrients and nitrogen fixation in groundnut (Selvam *et al.*, 1989). Rao *et al.*, (1988) also found that water deficit reduced nutrient uptake by groundnut plant. Decrease in major nutrients like N, P and K uptake in groundnut varied with cultivars (Polara *et al.*, 1984). Soil moisture stress at vegetative, flowering, pegging and pod development stages of groundnut was found to decrease N content in the shoot and pod and increase P, K, Ca and Mg in the shoot and pod (Patel *et al.*, 1984).

Reduced uptake of K under moisture stress was reported by reported by Patel and Padalia (1980) in groundnut and by Shahid Umar *et al.* (1993) in sorghum. N content of plants decreased number of nodules. plant⁻¹, reduced nitrogenase activity and nitrogen fixation in soybean (Chandel *et al.*, 1995).

Moisture stress imposed at seedling stage also resulted in reduction of nitrogen, phosphorus and potassium in the shoot in rice (Baruah *et al.*, 1998).

Materials and Methods

CHAPTER - III

MATERIALS AND METHODS

The present investigation was carried out during *rabi* of 2000-2001 at Agricultural College Farm, Bapatla to study effect of drought stress on growth and yield of groundnut and the role of foliar sprays in ameliorating drought stress. The details of the experiment conducted are explained in this chapter.

3.1 EXPERIMENTAL SITE

A field experiment was conducted in sandy loam soils of Orchard block at Agricultural College Farm, Acharya NG Ranga Agricultural University, Bapatla, Andhra Pradesh, which is 7km distant from Bay of Bengal with an altitude of 5.49 m above MSL, 15°54' N E latitude and longitude of 80°25' E.

3.2 WEATHER DATA

The data on weather parameters like temperature, relative humidity and rainfall recorded during the crop growth period are presented in Table 1. The weekly mean maximum and mean minimum temperatures during the crop growth period ranged from 32.4°C to 28.9°C and 15.8°C to 23.1°C respectively,

Table 1: Weekly weather data during the crop growth period (December 3, 2000 to March 25, 2001).

Standard Week	Date & Month	Temperature ($^{\circ}\text{C}$)		Relative Humidity (%)	Rainfall (mm)
		Max.	Min.		
49	03.12.00–09.12.00	29.80	18.50	81.90	0.24
50	10.12.00–06.12.00	29.70	16.40	81.50	--
51	17.12.00–03.12.00	29.40	15.80	75.50	--
52	24.12.00–01.12.00	28.90	16.40	75.00	--
01	01.01.01–07.01.01	29.00	18.90	79.40	--
02	08.01.01–14.01.01	29.00	17.80	82.00	--
03	15.01.01–20.01.01	29.60	17.70	81.90	--
04	21.01.01–28.01.01	30.30	15.90	78.40	--
05	29.01.01–04.02.01	29.00	14.70	79.00	--
06	05.02.01–11.02.01	32.20	17.60	81.10	--
07	12.02.01–18.02.01	30.30	17.40	81.50	--
08	19.02.01–25.02.01	31.30	20.60	84.60	--
09	26.02.01–04.03.01	31.30	21.90	78.90	--
10	05.03.01–11.03.01	31.70	20.60	72.20	--
11	12.03.01–18.03.01	32.30	21.00	70.90	--
12	19.03.01–25.03.01	32.40	23.10	79.10	--
Total Mean		30.38	18.39	78.93	0.24

with an average maximum temperature of 30.38°C and average minimum temperature of 18.39°C . The weekly mean relative humidity during the crop growth period ranged from 70.9 per cent to 84.6 per cent with an average of 78.93 per cent. Rainfall of 0.24 mm recorded in 49th standard week occurred before sowing the crop.

3.3 EXPERIMENTAL DETAILS

A field experiment was conducted to study the physiology of foliar nutrition of groundnut under drought stress. The plan and experimental lay out are given in Fig.1. The experiment was conducted by adopting Factorial RBD with additional treatment design replicated 3 times.

3.3.1 Field Preparation

The experimental field was ploughed four times using a tractor drawn cultivator. Weeds and stubbles were removed and the field was leveled and laid out into plots as per the design.

3.3.2 Fertilizer Application

Nitrogen, phosphorous and potassium were applied as per the recommendations i.e., 20 Kg N ha^{-1} , $17.5\text{ Kg P}_2\text{O}_5\text{ ha}^{-1}$ and 33 Kg K ha^{-1} at the time of sowing.

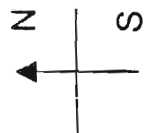
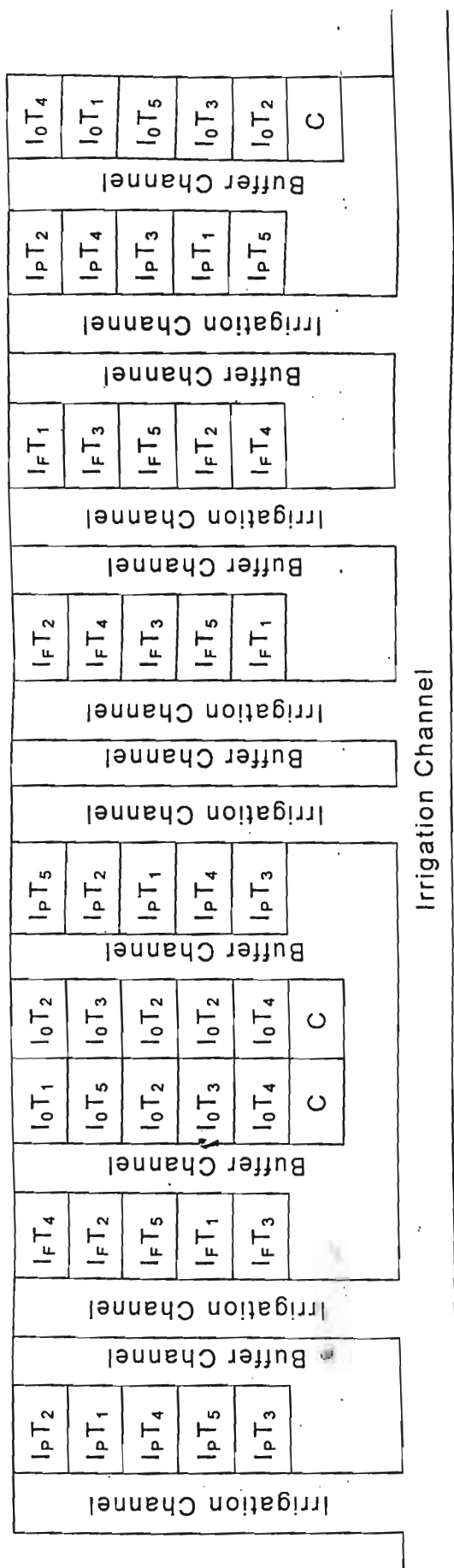


Fig. 1 LAY OUT PLAN



Replication I

Replication II

Replication III

Design : Factorial RBD with additional treatment

Replications : Three

Season : Rabi

Spacing : 30 x 10 cm

Plot size : 4m x 3m

Factor I :

I_F : Irrigation at 30 DAS

I_P : Irrigation at 55 DAS

I₀ : No Irrigation

T₁ : Water spray (control)

T₂ : Urea (0.5%)

T₃ : Urea (0.5%) + sugar (0.25%)

T₄ : Urea (0.5%) + sugar (0.25%) + K₂SO₄ (0.25%)

T₅ : Urea (0.5%) + K₂SO₄ (0.25%)

Control : C : No irrigation and no foliar spray

3.3.3 Seeds and Sowing

Bold and healthy seed of TMV-2 (Spanish bunch type variety with green foliage requiring about 105 days to mature. It has shelling percentage of 77 per cent and seed oil content of 49 per cent possessing yield potential of 12-16 q ha⁻¹) was obtained from nearby research station of ANGRAU. Sowing was done by dibbling method on 5.12.2000 at a depth of 5 cm with the recommended spacing of 30 x 10 cm. Pre-sowing irrigation was given to all the experimental plots.

3.3.4 Management Practices

3.3.4.1 Weeding

Weeding was done manually at 15 days after sowing and at 45 days after sowing in all the plots.

3.3.4.2 Plant protection

The crop was given adequate plant protection by treating the seed with Carbendazim @ 2 g kg⁻¹ at the time of sowing and spraying with Bavistin @ 1g L⁻¹ to control the leaf spot and with Monocrotophos @ 2 mL L⁻¹ to control pests.

3.3.4.3 Irrigation

Irrigation was given to the plots before and 2 days after sowing. Irrigation treatments were imposed as per the following treatment schedule.

Treatments

1. I_F = Irrigation at first flowering stage (30 DAS).
2. I_P = Irrigation at pegging stage (55 DAS).
3. I_0 = Drought.
4. Control = No irrigation.

3.3.4.4 Foliar nutrition

Foliar spraying of nutrients (urea, K_2SO_4 and sugar) was done as per the treatments i.e., at 20 DAS in I_F , at 45 DAS in I_P and at 80 DAS in I_0 . Spraying was not done in control plot.

T_1 = Water spray (control)

T_2 = Urea (0.5%)

T_3 = Urea (0.5%) + Sugar (0.25%)

T_4 = Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%)

T_5 = Urea (0.5%) + K_2SO_4 (0.25%)

3.4 HARVESTING

The crop was considered physiologically mature when more than 70 per cent of randomly sampled pods showed dark streaks inside the shell. The plants were hand pulled and pods were stripped. Harvesting was done separately for each plot and the final net population was recorded. Yield and yield components such as number of plants m^{-2} , number of pods plant^{-1} , number of kernels pod^{-1} and test weight were recorded.

3.5 GROWTH ANALYSIS

Observations were recorded from 5 plants plot^{-1} at every 15 days interval. Growth characters like plant height, number of branches, number of leaves, leaf area, dry weight of stem and leaves, days to 50 per cent flowering and physiological parameters like relative water content, stomatal resistance and leaf temperature were recorded at 15 days interval. Biochemical estimation of proline content was done at 55 days after sowing.

3.5.1 Non-destructive Growth Analysis

Five adjacent plants were tagged in each plot and observations like plant height, number of branches plant^{-1} and number of leaves plant^{-1} were taken on these plants. Stomatal

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3.5.1 Non-destructive Growth Analysis

Five adjacent plants were tagged in each plot and observations like plant height, number of branches $plant^{-1}$ and number of leaves $plant^{-1}$ were taken on these plants. Stomatal

resistance and leaf temperature were also recorded on the same dates.

3.5.1.1 Plant height (cm)

Plant height was taken from base of the plant to the apex. The values were averaged and expressed for three replications.

3.5.1.2 Number of branches plant⁻¹

Number of primary branches on the main stem were counted and recorded at 15 days interval.

3.5.1.3 Number of leaves plant⁻¹

Number of photosynthetically active leaves was recorded on each plant at every sampling date.

3.5.1.4 Days to 50 per cent flowering

Days to 50 per cent flowering was recorded when more than 50 per cent of the plants in each plot showed flowering.

3.5.2 Destructive Growth Analysis

Five adjacent plants were collected from 0.15 m⁻² area in each plot at 15 days interval. Data on leaf area, dry weight of stem and leaf, leaf relative water content were recorded at 15 days interval and proline content was determined at 55 days after sowing.

3.5.2.1 Leaf area (cm² plant⁻¹)

Leaves were separated from freshly collected plant samples and the leaf area was determined directly with the help of automatic leaf area meter (ΔT).

3.5.2.2 Dry weight of stem and leaf (g plant⁻¹)

The plants were separated in to leaves and stem and are dried in hot air oven at 80 °C for 48 h to a constant weight and their dry weights were recorded using electronic balance.

3.6 GROWTH PARAMETERS

The following growth parameters were calculated from the above primary data.

3.6.1 Leaf Area Index (LAI)

Leaf area was estimated from the automatic leaf area meter (ΔT). LAI is the functional size of the crop standing on land area. Leaf area index was calculated from the formula (Watson, 1947).

$$LAI = LA/P$$

Where LA = Leaf area P = unit of land area.

3.6.2 Specific Leaf Weight (SLW) (mg cm^{-2})

The specific leaf weight was calculated by the following formula (Donald, 1962).

$$SLW = LW / LA$$

Where, LW represent leaf dry weight and LA represent leaf area.

3.6.3 Relative Growth Rate (RGR) ($\text{mg g}^{-1} \text{d}^{-1}$)

RGR was calculated by the following formula suggested by Fisher (1971).

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1} \quad (\text{mg g}^{-1} \text{d}^{-1})$$

Where $\log_e$ = Natural logarithms

W_1 and W_2 represent phytomass at the beginning and end of time t_1 and t_2 respectively.

3.7 PHYSIOLOGICAL PARAMETERS

3.7.1 Relative water content (%)

The plant water status was measured by determining the relative water content of the leaf fortnightly. Fully expanded and matured leaves were excised from the plant and the fresh weight was recorded. The leaves were then immersed in a thin film of water for one hour and then gently blotted before taking turgid weight. Afterwards leaves were oven-dried at 75°C and weight of these leaves was recorded. These recorded values were substituted in the formula given by Slatyer and Mcilroy (1967) to determine the relative water content.

$$RWC (\%) = \frac{W_f - W_d}{W_t - W_d} \times 100$$

W_f = Weight of fresh leaves.

W_t = Weight of turgid leaves.

W_d = Weight of oven dried leaves.

3.7.2 Stomatal resistance ($S\text{ cm}^{-1}$)

Stomatal resistance was determined with automatic porometer at 15 days interval both in control and treated plants. Calibration graph was drawn with known resistance values and their relative counts. Finally the counts obtained from the leaf in automatic porometer were interpreted on the graph to get stomatal resistance value of the leaf.

3.7.3 Leaf temperature ($^{\circ}\text{C}$)

The temperature ($^{\circ}\text{C}$) on the leaf upper surface was recorded with infrared thermometer.

3.8 BIOCHEMICAL PARAMETER

3.8.1 Proline Content ($\mu\text{g g}^{-1}$ fresh weight)

Proline content in the leaves was estimated at 15 days interval by following the method of Bates *et al* (1973). 500 mg of fresh leaf material was weighed and homogenized in 10 mL of 3 per cent sulphosalicylic acid. The homogenized mixture was filtered and the volume of the filtrate was made upto 25 mL. 2 mL of the extract was taken in a test tube and 2mL of glacial acetic acid was added to it and thoroughly mixed. To that solution 2 mL of acid ninhydrin was added (acid ninhydrin was prepared by dissolving 2.5 g of ninhydrin powder in 60 mL of

glacial acetic acid and 40 mL of orthophosphoric acid) and kept in a boiling water bath maintained at 100°C for 60 minutes. The test tube was brought to room temperature and to it 4 mL of toluene was added. After thorough shaking, the toluene fraction was separated and the optical density was determined at 520 nm in spectronic-20.

$$\text{Proline } (\mu\text{g g}^{-1} \text{ fresh weight}) = \frac{\text{O.D} \times 36.231 \times V}{Y \times W}$$

O.D = Optical density at 520 nm.

V = Final volume of the extract.

Y = Volume of the aliquot taken.

W = Weight of the plant material.

3.9 YIELD ANALYSIS

Groundnut crop was harvested from 576 m² area. Plants from each plot were harvested and kept separately.

3.9.1 Number of Plants m⁻²

Number of plants m⁻² was determined by counting the number of plants plot⁻¹ and calculating per square meter.

3.9.2 Number of Pods Plant⁻¹

All the pods from sampled plants were counted and averaged.

3.9.3 Number of Kernels Plant⁻¹

Kernels in the pods collected from sampled plants were counted and calculated as number of kernels pod⁻¹.

3.9.4 Test Weight (g)

From the shelled out pod samples, weight of seed lots were taken and number of kernels in each lot was counted and 100-kernel weight (test weight) was calculated.

3.9.5 Pod Yield (kg ha⁻¹)

After drying the pods from each plot, yield per plot was recorded by weighing the pods. Based on plot yield, the yield was worked out for each treatment and expressed in kg ha⁻¹.

3.9.6 Haulm Yield (kg ha⁻¹)

Phytomass of the plants from the collected plant samples at harvest was weighed after oven drying and calculated per hectare.

3.9.7 Harvest Index (HI)

Harvest index was computed to find out the efficiency of treatments in utilizing the photosynthates for pod production. Harvest index was calculated by adopting the following formula (Donald, 1962).

$$\text{Harvest index} = \frac{\text{Pod yield}}{\text{Whole plant biomass}}$$

3.10 STATISTICAL ANALYSIS

The experimental data were analysed statistically following Factorial RBD with additional treatment design (Rangaswamy, 1995). Statistical significance was tested by "F" value at 5 per cent level of probability. Critical difference was worked out at 5 per cent.

Results

CHAPTER - IV

RESULTS

Investigations on the physiology of foliar nutrition of groundnut with drought stress were carried out on sandy loam soil at College Farm, Agricultural College, Bapatla during *rabi* season 2000-2001. The results of the growth and yield components including physiological parameters were analysed statistically and are presented with different sub heads, in the following paragraphs.

4.1 GROWTH CHARACTERS

4.1.1 Plant Height

The data on plant height (cm) as influenced by treatments is shown in Table 2 and represented in Fig.2. There was significant difference between the control plot (where the crop was grown on receding soil moisture with out sprayings and irrigation) and rest of the treatments at 45, 60, 75, 90 DAS and at harvest.

A significant difference in plant height due to spraying treatments was observed at 45 DAS. Foliar spray of nutrients increased the plant height significantly at 45 DAS over water spray. Foliar spray of Urea (0.5%) + Sugar (0.25%) + K₂SO₄

(0.25%) was found to produce maximum plant height (9.6 cm) at 45 DAS.

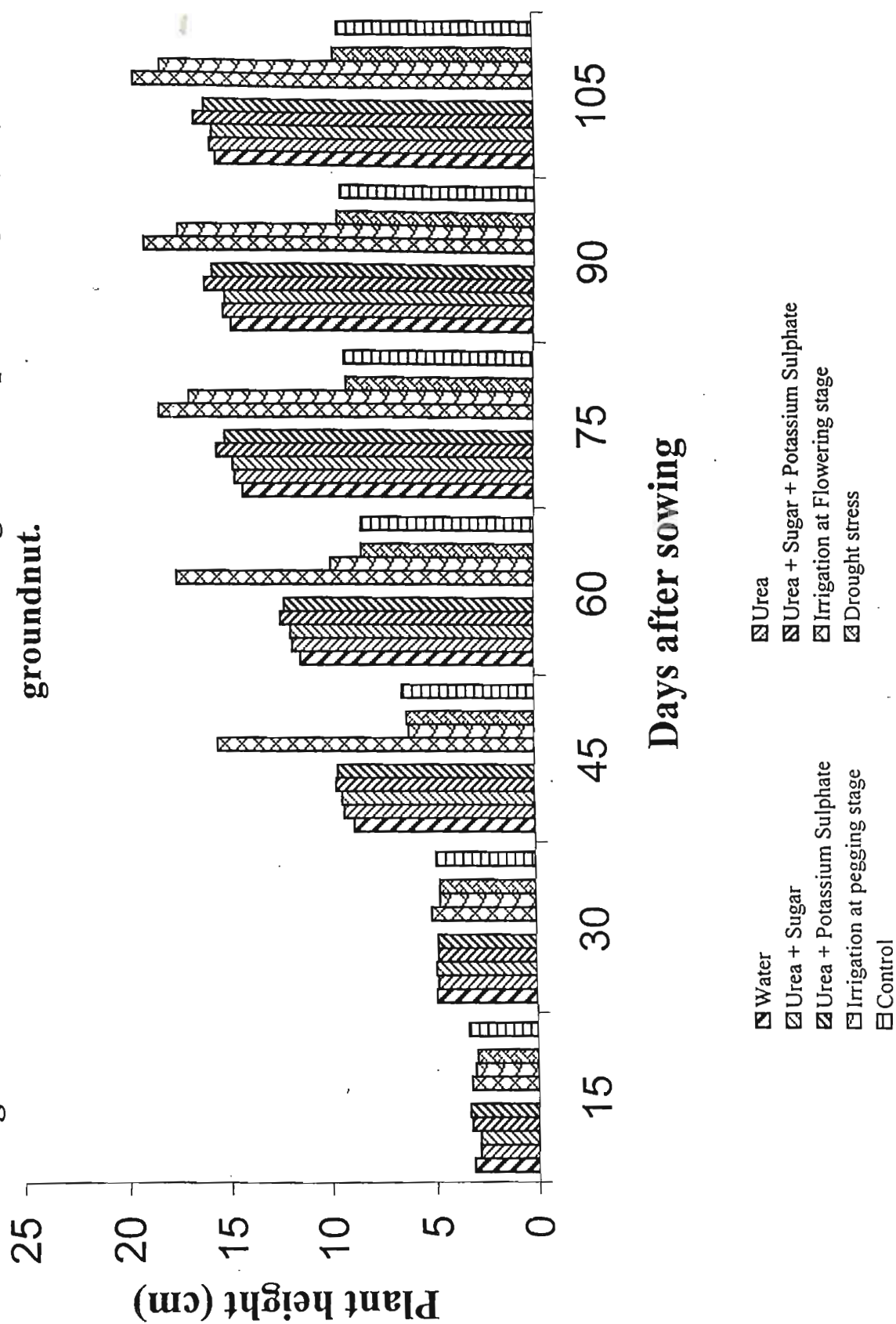
Irrigation significantly increased the plant height over drought treatment at 45, 60, 75, 90 DAS and at harvest. Irrigation 30 DAS significantly increased the plant height at 45, 60, 75, 90 DAS and at harvest. Irrigation at 55 DAS significantly increased the plant height at 60, 75, 90 DAS and at harvest over drought treatment. Between two different times of irrigation, irrigation at 30 DAS produced the highest plant height (19.5 cm) at harvest and lowest plant height was observed in drought conditions (9.8) at harvest.

Foliar spray at 20 DAS when followed by irrigation at 30 DAS produced significant interaction effect at 45 DAS. Among different nutrient sprays, foliar spray of Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) followed by irrigation at 30 DAS produced the highest plant height at 45 DAS (16.7) and it was on par with Urea (0.5%) + K_2SO_4 (0.25%) (16.2). Plant height produced by the foliar spray of Urea (0.5%) + Sugar (0.25%) was on par with the plant height produced by the foliar spray of Urea (0.5%) and Urea (0.5%) + K_2SO_4 (0.25%) but, significantly differed from the water spray. From 45 DAS till harvest foliar spray of nutrients at 20 DAS followed by irrigation at 30 DAS did not differ significantly from the water spray. Foliar sprays at 80

Table 2: Effect of nutrient sprays and irrigation on the plant height (cm) of groundnut.

Treatments	Days after sowing						Harvest
	15	30	45	60	75	90	
Water	3.2	4.9	8.7	11.3	14.1	14.7	15.4
Urea	2.9	4.8	9.2	11.7	14.5	15.1	15.7
Urea + Sugar	2.9	4.9	9.3	11.8	14.6	15.0	15.6
Urea + Sugar + K ₂ SO ₄	3.3	4.8	9.6	12.3	15.4	16.0	16.5
Urea + K ₂ SO ₄	3.4	4.8	9.5	12.1	15.0	15.6	16.0
Sem ±	0.1	0.1	0.1	0.2	0.3	0.3	0.3
C. D (0.05)	NS	NS	0.4	NS	NS	NS	NS
I _F (30 DAS)	3.3	5.1	15.5	17.5	18.3	19.0	19.5
I _P (55 DAS)	3.1	4.7	6.1	9.8	16.8	17.3	18.2
I _O (Drought)	3.0	4.7	6.2	8.3	9.0	9.5	9.8
Sem ±	0.1	0.1	0.1	0.2	0.2	0.2	0.2
C. D (0.05)	NS	NS	0.4	0.6	0.7	0.7	0.7
I _F Water	3.1	4.8	13.7	16.4	17.2	18.0	18.5
Urea	2.9	5.0	15.3	17.0	17.6	18.4	18.8
Urea + Sugar	3.3	5.1	15.7	17.3	18.4	18.9	19.2
Urea + Sugar + K ₂ SO ₄	3.4	5.3	16.7	18.3	19.4	20.1	20.9
Urea + K ₂ SO ₄	3.6	5.2	16.2	18.5	19.1	19.8	20.1
I _P Water	3.4	4.8	6.0	9.5	16.2	16.8	18.4
Urea	2.8	4.5	5.9	9.7	16.6	17.1	17.8
Urea + Sugar	2.7	4.8	6.2	9.6	16.7	17.3	18.1
Urea + Sugar + K ₂ SO ₄	3.5	4.9	6.3	10.2	17.4	18.0	18.5
Urea + K ₂ SO ₄	3.3	4.7	6.2	9.9	16.9	17.4	18.2
I _O Water	3.1	5.1	6.3	8.2	8.8	9.2	9.4
Urea	3.0	4.8	6.4	8.5	9.4	9.9	10.4
Urea + Sugar	2.6	4.7	6.0	8.3	8.7	9.0	9.5
Urea + Sugar + K ₂ SO ₄	3.0	4.2	5.9	8.5	9.3	9.8	10.0
Urea + K ₂ SO ₄	3.3	4.5	6.2	8.0	9.0	9.5	9.8
Sem ±	0.2	0.3	0.3	0.5	0.5	0.5	0.5
C. D (0.05)	NS	NS	0.8	NS	NS	NS	NS
Control	3.4	4.9	6.4	8.3	9.1	9.4	9.6
Control Vs Rest	3.1	4.8	9.3	11.8	14.7	15.3	15.8
Sem ±	0.2	0.2	0.2	0.4	0.4	0.4	0.4
C. D (0.05)	NS	NS	0.6	1.0	1.1	1.1	1.1
CV %	13.5	10.1	5.5	7.2	6.4	6.2	6.1

Fig. 2 Effect of foliar nutrition and irrigation on plant height (cm) of groundnut.



DAS under drought stress did not show any significant effect on the plant height.

4.1.2 Number of Branches

The data presented in the Table 3 and represented in Fig.3 shows that rest of the treatments did not significantly increased the number of branches plant⁻¹ at 45, 75, 90 DAS and at harvest over control, where the plants were grown with receding soil moisture conditions with out sprayings and irrigation.

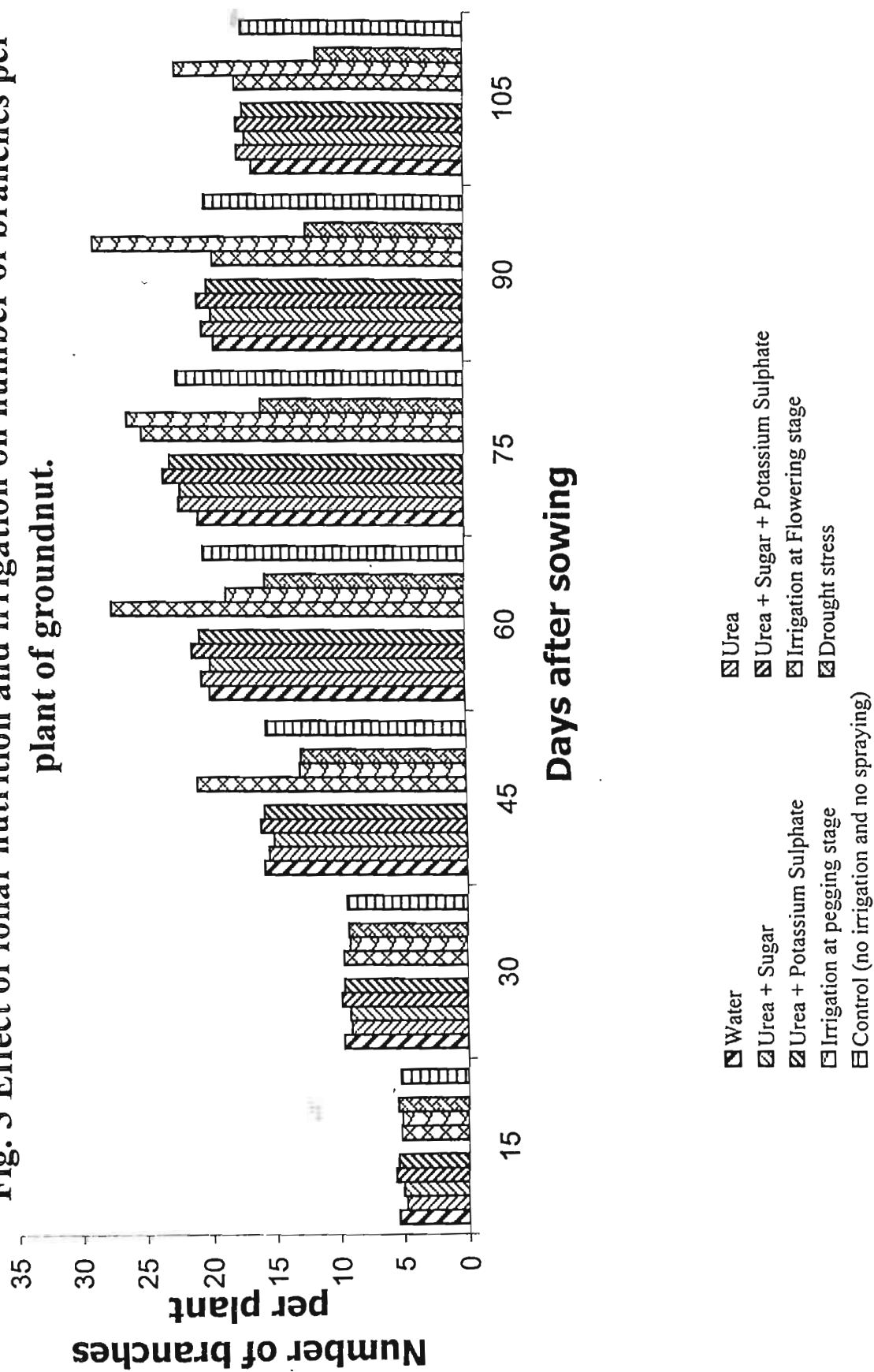
There was no significant effect of nutrient sprays on the number of branches plant⁻¹. Irrigation given either at 30 or 55 DAS significantly increased the number of branches plant⁻¹ over drought treatment. Irrigation at 30 DAS increased the number of branches plant⁻¹ significantly at 45, 60, 75, 90 DAS and at harvest. Irrigation at 55 DAS also significantly increased the number of branches plant⁻¹ at 75, 90 DAS and at harvest. Increase in the number of branches plant⁻¹ was high (4.2) when irrigation was given at 30 DAS than with irrigation at 55 DAS (4.09). Least number of branches plant⁻¹ (3.5) was produced in drought (I₀) treatment where plants were grown with residual moisture conditions.

Table 3: Effect of nutrient sprays and irrigation on the number of branches plant⁻¹ of groundnut.

Treatments	Days after sowing						Harvest
	15	30	45	60	75	90	
Water	2.0	2.9	3.5	3.7	3.9	3.9	3.9
Urea	2.0	2.8	3.4	3.7	3.9	3.9	3.9
Urea + Sugar	1.9	2.8	3.5	3.8	4.0	4.0	4.0
Urea + Sugar + K ₂ SO ₄	2.0	2.7	3.5	3.8	4.0	4.0	4.0
Urea + K ₂ SO ₄	2.0	2.8	3.6	3.8	3.9	3.9	3.9
Sem ±	0.03	0.1	0.1	0.1	0.1	0.1	0.1
C. D (0.05)	NS	NS	NS	NS	NS	NS	NS
I _F (30 DAS)	2.0	2.8	4.1	4.2	4.2	4.2	4.2
I _P (55 DAS)	2.0	2.8	3.2	3.6	4.1	4.1	4.1
I _O (Drought)	2.0	2.8	3.2	3.5	3.5	3.5	3.5
Sem ±	0.03	0.1	0.1	0.1	0.1	0.1	0.1
C. D (0.05)	NS	NS	0.2	0.3	0.2	0.2	0.2
I _F Water	2.0	2.9	4.1	4.1	4.1	4.1	4.1
Urea	2.0	2.8	4.0	4.2	4.2	4.2	4.2
Urea + Sugar	1.8	2.9	4.1	4.2	4.2	4.2	4.2
Urea + Sugar + K ₂ SO ₄	2.0	2.7	4.1	4.3	4.3	4.3	4.3
Urea + K ₂ SO ₄	2.0	3.0	4.2	4.2	4.2	4.2	4.2
I _P Water	2.0	2.8	3.2	3.4	4.0	4.0	4.0
Urea	2.0	2.9	3.2	3.6	4.1	4.1	4.1
Urea + Sugar	2.0	2.9	2.9	3.6	4.0	4.0	4.0
Urea + Sugar + K ₂ SO ₄	2.0	2.8	3.1	3.7	4.2	4.2	4.2
Urea + K ₂ SO ₄	2.0	2.7	3.4	3.9	4.1	4.1	4.1
I _O Water	2.0	3.0	3.2	3.6	3.6	3.6	3.6
Urea	2.0	2.8	3.0	3.4	3.4	3.4	3.4
Urea + Sugar	2.0	2.8	3.4	3.7	3.7	3.7	3.7
Urea + Sugar + K ₂ SO ₄	1.9	2.8	3.2	3.6	3.6	3.6	3.6
Urea + K ₂ SO ₄	2.0	2.8	3.2	3.3	3.3	3.3	3.3
Sem ±	0.06	0.1	0.2	0.2	0.2	0.2	0.2
C. D (0.05)	NS	NS	NS	NS	NS	NS	NS
Control	2.0	3.0	3.1	3.6	3.6	3.6	3.6
Control Vs Rest	2.0	2.8	3.5	3.8	3.9	3.9	3.9
Sem ±	0.05	0.1	0.1	0.1	0.1	0.1	0.1
C. D (0.05)	NS	NS	0.4	NS	0.4	0.4	0.4
CV %	5.6	8.9	9.0	9.2	7.7	7.7	7.7



Fig. 3 Effect of foliar nutrition and irrigation on number of branches per plant of groundnut.



Number of branches plant⁻¹ showed an increase upto 60 DAS and later remained constant both in drought (3.5) and irrigation at 30 DAS treatment (4.2). In irrigation at 55 DAS number of branches plant⁻¹ increased upto 75 DAS (4.09) and did not increase later. Foliar spray of nutrients followed by irrigation did not show significant effect on the number of branches plant⁻¹.

4.1.3 Number of Leaves

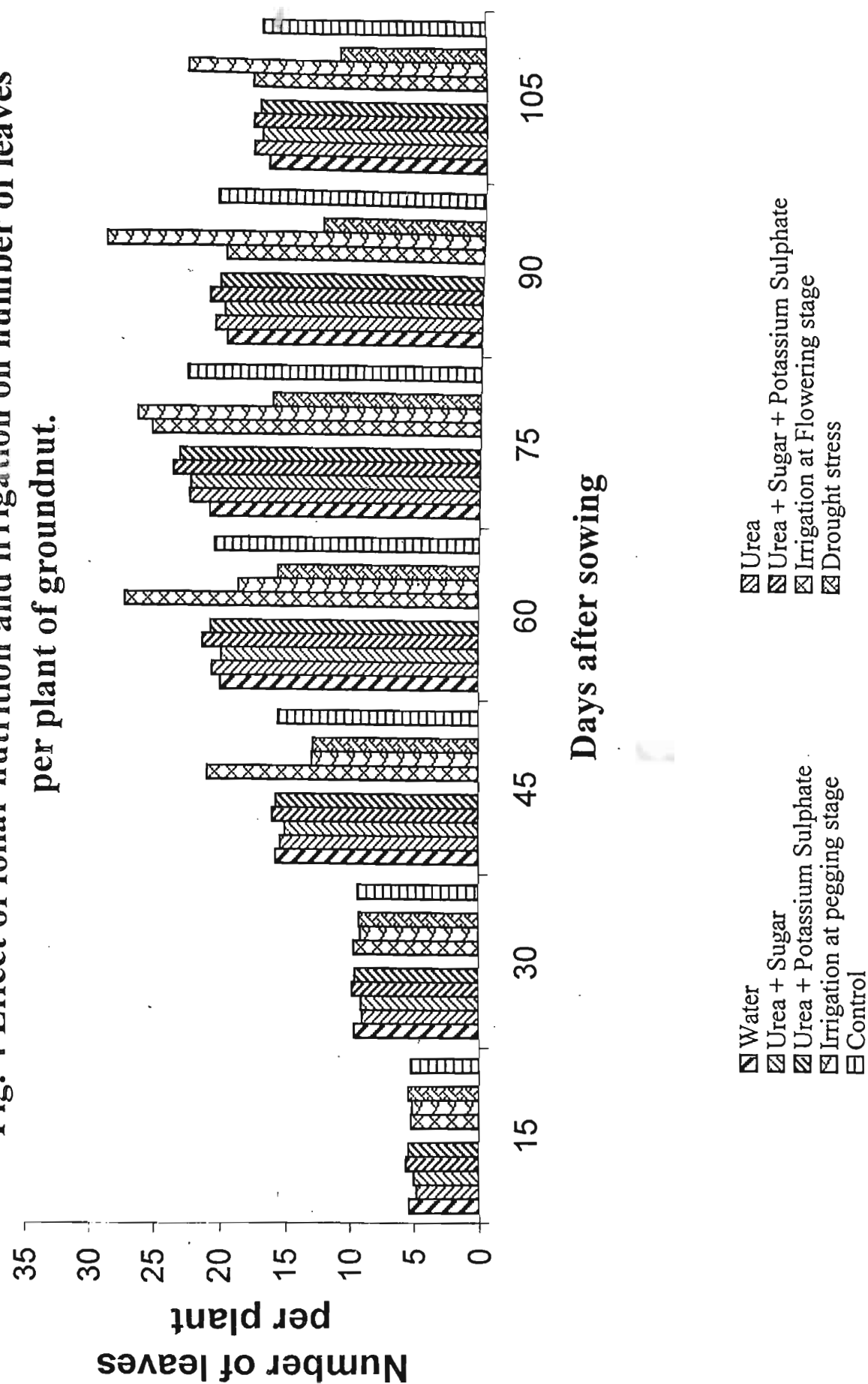
The data on the number of leaves plant⁻¹ as influenced by nutrient sprays and irrigation is presented in Table 3 and represented in Fig. 4. There was significant difference between the control plants and the rest of the treatment plants with respect to the number of leaves at 45, 60, 75 and 90 DAS and at harvest. Foliar spray of nutrients did not significantly increase the number of leaves plant⁻¹ over water spray except at 75 DAS. The number of leaves were more with foliar spray of Urea (0.5%) + Sugar (0.25%) + K₂SO₄ (0.25%) spray (23.7) followed by Urea (0.5%) + K₂SO₄ (0.25%) spray (23.2).

A significant increase in the number of leaves plant⁻¹ was observed with irrigation. Irrigation at 30 DAS significantly increased the number of leaves plant⁻¹ at 45, 60, 75, 90 DAS and at harvest. In irrigation at 30 DAS number of leaves plant⁻¹ increased upto 60 DAS (27.6) and decreased later. Irrigation at 55 DAS also significantly increased the number of leaves plant⁻¹

Table 4: Effect of nutrient sprays and irrigation on the number of leaves plant⁻¹ of groundnut.

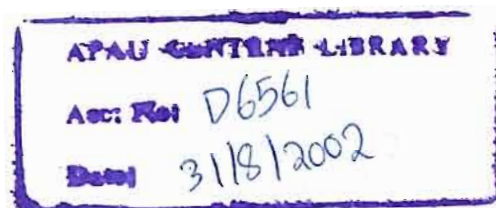
Treatments	Days after sowing						Harvest
	15	30	45	60	75	90	
Water	5.4	9.6	15.8	20.1	21.0	19.7	16.5
Urea	4.8	9.0	15.4	20.7	22.5	20.6	17.7
Urea + Sugar	5.0	9.1	15.0	20.0	22.4	19.9	17.1
Urea + Sugar + K ₂ SO ₄	5.6	9.8	16.0	21.4	23.7	21.0	17.8
Urea + K ₂ SO ₄	5.4	9.6	15.7	20.8	23.2	20.2	17.3
Sem ±	0.2	0.3	0.3	0.3	0.4	0.4	0.3
C. D (0.05)	NS	NS	NS	NS	1.3	NS	NS
I _F (30 DAS)	5.2	9.7	21.0	27.6	25.3	19.7	17.9
I _P (55 DAS)	5.1	9.2	12.9	18.7	26.4	29.0	22.7
I _O (Drought)	5.4	9.3	12.8	15.6	16.0	12.2	11.3
Sem ±	0.2	0.3	0.3	0.3	0.4	0.3	0.3
C. D (0.05)	NS	NS	0.9	0.9	1.1	1.0	0.7
I _F Water	5.0	9.8	20.9	26.4	23.6	19.7	17.4
Urea	4.7	9.0	20.6	27.3	24.9	20.0	18.0
Urea + Sugar	5.2	9.4	20.8	26.7	24.9	18.8	17.4
Urea + Sugar + K ₂ SO ₄	5.7	10.2	21.9	29.0	27.2	20.5	18.6
Urea + K ₂ SO ₄	5.4	10.2	21.1	28.7	26.1	19.6	17.9
I _P Water	5.6	9.8	13.7	17.9	23.1	26.9	20.8
Urea	4.2	8.6	12.3	18.4	26.1	28.9	22.9
Urea + Sugar	4.7	8.9	12.2	18.6	26.7	29.5	22.9
Urea + Sugar + K ₂ SO ₄	5.9	9.6	12.8	19.4	28.0	30.3	23.7
Urea + K ₂ SO ₄	5.3	9.3	13.4	18.9	28.0	29.2	23.2
I _O Water	5.7	9.2	12.9	16.0	16.3	12.7	11.2
Urea	5.4	9.3	13.3	16.2	16.7	12.8	12.2
Urea + Sugar	5.0	8.9	12.1	14.9	15.6	11.4	11.0
Urea + Sugar + K ₂ SO ₄	5.4	9.8	13.3	15.9	15.9	12.1	11.2
Urea + K ₂ SO ₄	5.6	9.3	12.6	15.0	15.7	11.9	10.8
Sem ±	0.4	0.6	0.7	0.7	0.9	0.8	0.6
C. D (0.05)	NS	NS	NS	NS	NS	NS	NS
Control	5.6	9.4	12.8	15.9	16.4	11.3	11.8
Control Vs Rest	5.2	9.4	15.6	20.6	22.6	20.3	17.3
Sem ±	0.3	0.5	0.5	0.5	0.6	0.6	0.4
C. D (0.05)	NS	NS	1.5	1.4	1.9	1.6	0.3
CV %	12.8	11.4	7.8	5.7	6.8	6.6	5.8

Fig. 4 Effect of foliar nutrition and irrigation on number of leaves per plant of groundnut.



at 60, 75, 90 DAS and at harvest. In this treatment number of leaves plant⁻¹ gradually increased upto 90 DAS (29.0) and decreased at harvest. With drought conditions number of leaves plant⁻¹ increased upto 75 DAS (16.02) and showed a decrease as crop advanced towards harvest. At 75 DAS number of leaves plant⁻¹ are on par with irrigation at 30 DAS and irrigation at 55 DAS.

Foliar spray of nutrients followed by irrigation did not significantly increase the number of leaves plant⁻¹. In control plants number of leaves plant⁻¹ increased gradually till 75 DAS and decreased later.



4.1.4 Leaf Area

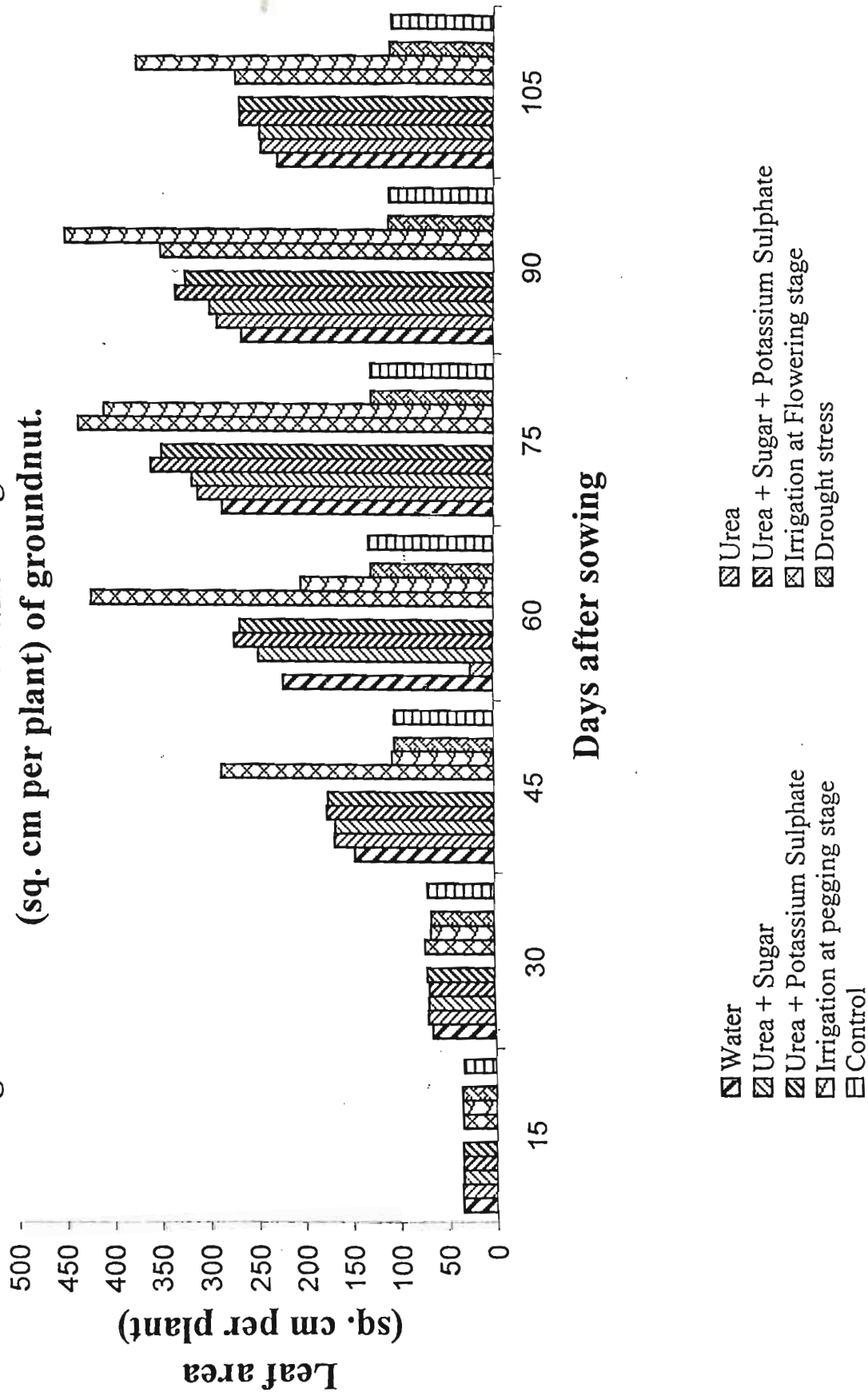
There was significant difference between the control plants and the rest of the treatment plants with respect to the leaf area (cm² plant⁻¹) at 45, 60, 75, 90 DAS and at harvest (Table 5 and Fig. 5).

Foliar nutrition significantly produced high leaf area over water spray at 45, 60, 75, 90 DAS and at harvest. There was no significant difference among the nutrient sprays at 45 DAS, however significantly highest leaf area was produced by Urea (0.5%) + Sugar (0.25%) + K₂SO₄ (0.25%) spray. At 60 DAS, 75 DAS and 90 DAS, Urea (0.5%) + Sugar (0.25%) + K₂SO₄

Table 5: Effect of nutrient sprays and irrigation on the leaf area ($\text{cm}^2 \text{ plant}^{-1}$) of groundnut.

Treatments	Days after sowing						Harvest
	15	30	45	60	75	90	
Water	34.9	64.5	146.9	221.3	285.2	269.6	231.4
Urea	35.7	69.1	168.3	252.4	312.9	293.7	249.3
Urea + Sugar	34.4	68.1	167.4	247.8	319.0	301.9	251.2
Urea + Sugar + K_2SO_4	34.8	67.8	176.2	275.6	361.5	335.8	272.9
Urea + K_2SO_4	35.0	69.9	174.5	268.0	352.7	327.8	273.4
Sem $\pm$	0.8	2.2	4.1	5.2	6.8	5.9	6.5
C. D (0.05)	NS	NS	12.0	15.2	19.5	17.0	18.8
I_F (30 DAS)	34.7	72.3	289.0	428.4	440.1	353.2	277.0
I_P (55 DAS)	35.1	65.9	106.8	204.1	412.4	455.3	381.3
I_O (Drought)	35.1	65.4	104.2	126.6	126.3	108.7	108.6
Sem $\pm$	0.7	2.0	3.7	4.7	6.0	5.3	5.8
C. D (0.05)	NS	NS	10.7	13.6	17.5	15.2	16.8
I_F Water	35.1	65.0	236.4	363.2	373.5	302.1	267.0
Urea	35.6	72.8	293.0	424.1	415.4	338.9	272.0
Urea + Sugar	33.6	70.4	286.7	419.2	430.0	347.2	274.7
Urea + Sugar + K_2SO_4	35.0	77.0	322.1	474.8	493.6	393.5	284.3
Urea + K_2SO_4	34.1	76.5	306.8	460.5	487.8	384.4	287.0
I_P Water	35.0	64.7	105.4	174.2	356.3	398.1	325.1
Urea	36.1	65.4	105.9	207.3	398.0	435.4	370.9
Urea + Sugar	33.6	65.2	109.1	200.4	402.2	448.8	365.9
Urea + Sugar + K_2SO_4	34.9	67.1	102.6	222.6	461.6	503.8	425.9
Urea + K_2SO_4	35.9	67.0	111.0	216.2	443.8	490.4	418.9
I_O Water	34.8	63.9	98.8	126.6	125.6	108.5	102.2
Urea	35.4	69.1	106.1	125.7	125.4	106.7	104.9
Urea + Sugar	36.1	68.6	106.3	124.0	124.7	109.7	113.1
Urea + Sugar + K_2SO_4	34.4	59.3	104.1	129.3	129.2	110.2	108.6
Urea + K_2SO_4	34.9	66.3	105.6	127.3	126.6	108.5	114.3
Sem $\pm$	1.6	4.4	8.3	10.5	13.5	11.8	13.0
C. D (0.05)	NS	NS	23.9	30.3	39.1	34.0	37.6
Control	33.3	70.2	104.5	124.9	127.4	105.8	106.5
Control Vs Rest	35.0	67.9	166.7	253.0	326.3	305.8	255.6
Sem $\pm$	1.2	3.2	6.1	7.7	9.9	8.6	9.5
C. D (0.05)	NS	NS	17.5	22.1	28.5	24.8	27.4
CV %	8.1	11.2	8.8	7.4	7.5	6.9	9.2

**Fig. 5 Effect of foliar nutrition and irrigation on leaf area
(sq. cm per plant) of groundnut.**



(0.25%) spray significantly increased leaf area and it was on par with the leaf area produced by the Urea (0.5%) + K_2SO_4 (0.25%) spray but both these sprays are significantly superior to the Urea (0.5%) and Urea (0.5%) + Sugar (0.25%) spray. At harvest Urea (0.5%) was not significantly differing from the water spray unlike other treatments.

Irrigation significantly increased leaf area development over drought stress. Irrigation at 30 DAS significantly produced highest leaf area over irrigation at 55 DAS and drought treatment at 45, 60 and 75 DAS. At 90 DAS and at harvest, irrigation at 55 DAS significantly resulted in higher leaf area production over irrigation at 30 DAS. Irrigation at 55 DAS produced higher leaf area over drought treatment at 60, 75, 90 DAS and at harvest. Among different treatments lowest leaf area production was recorded with drought treatment (I_0).

Foliar spray of nutrients, Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) and Urea (0.5%) + K_2SO_4 (0.25%) at 20 DAS followed by irrigation at 30 DAS significantly increased leaf area at 45, 60, 75 and 90 DAS over Urea (0.5%) and Urea (0.5%) + Sugar (0.25%), unlike at harvest there was no significant difference between the nutrient sprays and water spray. Foliar spray of nutrients at 45 DAS followed by irrigation at 55 DAS significantly increased leaf area over water spray at 60, 75, 90

DAS and at harvest, however there was no significant difference with in the nutrient sprays at 60 DAS. At 75, 90 DAS and at harvest foliar spray of Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) significantly produced highest leaf area and it was on par with the leaf area produced by the foliar spray of Urea (0.5%) + K_2SO_4 (0.25%) and these two sprays significantly produced more leaf area than the Urea (0.5%) and Urea (0.5%) + Sugar (0.25%). Foliar sprays at 80 DAS under drought stress did not show any significant effect on leaf area production.

4.1.5 Stem Dry Weight

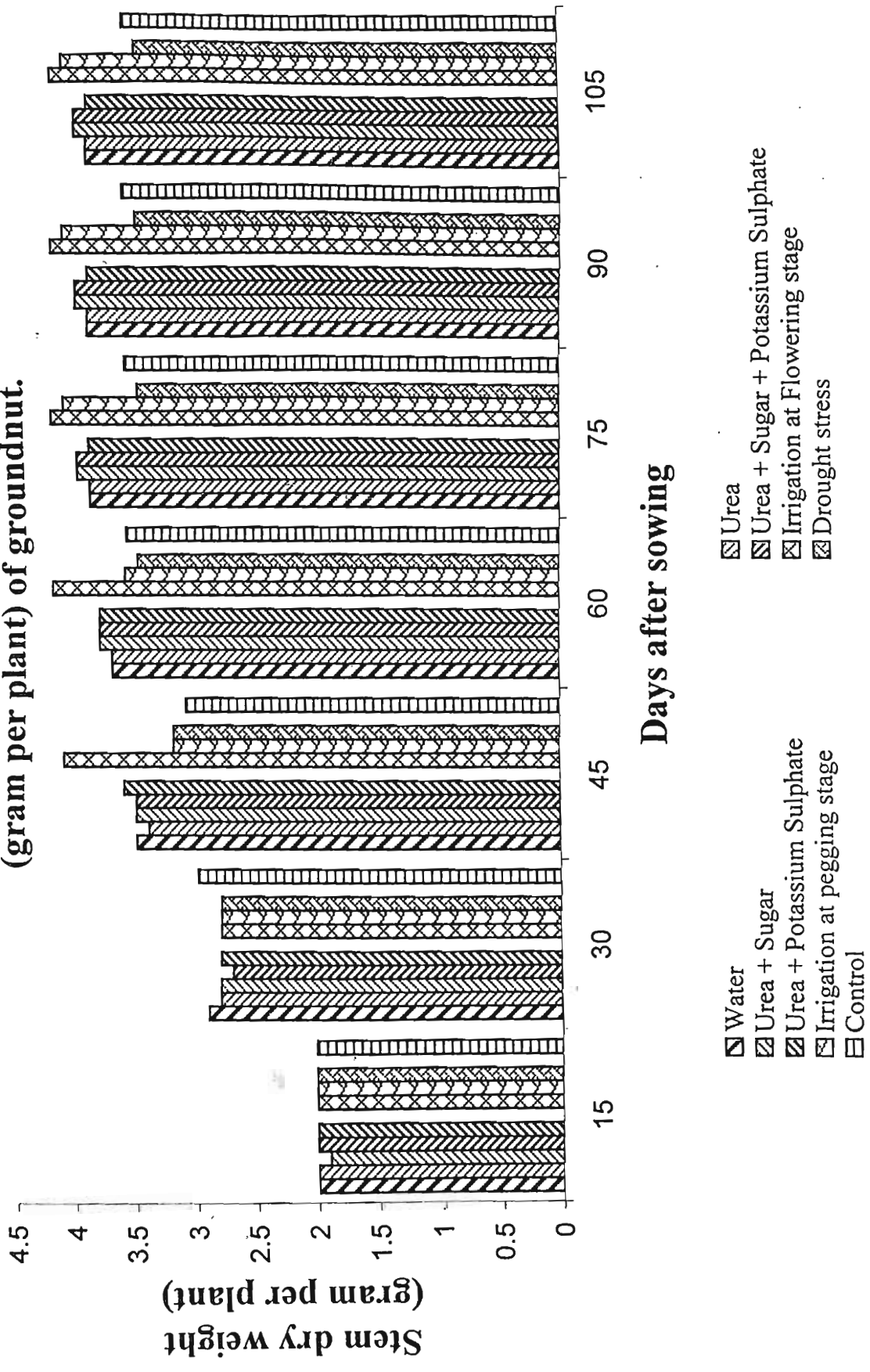
The results presented in Table 6 and depicted in Fig. 6 indicate that there was significant difference between the control plants and the rest of the treatment plants with respect to the stem dry weight ($g\ plant^{-1}$) at 45, 60, 75, 90 DAS and at harvest.

Significant increase in stem dry weight was observed due to foliar application of different nutrients at 45, 60, 75, 90 DAS and at harvest over water spray. The highest stem dry matter accumulation was noticed with the foliar nutrition of Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) followed by Urea (0.5%) + K_2SO_4 (0.25%) spray and these were on par with each other and significantly higher than the water spray at 45, 60, 75, 90 DAS and at harvest. At 45 DAS stem dry weight observed with

Table 6: Effect of nutrient sprays and irrigation on the stem dry weight (g plant⁻¹) of groundnut.

Treatments	Days after sowing						Harvest
	15	30	45	60	75	90	
Water	0.12	0.28	0.68	1.41	2.05	1.87	1.39
Urea	0.10	0.28	0.78	1.58	2.37	2.07	1.60
Urea + Sugar	0.10	0.29	0.75	1.62	2.41	2.09	1.69
Urea + Sugar + K ₂ SO ₄	0.11	0.29	0.90	1.85	2.65	2.27	1.81
Urea + K ₂ SO ₄	0.12	0.30	0.84	1.83	2.63	2.21	1.79
Sem ±	0.00	0.01	0.02	0.03	0.05	0.04	0.04
C. D (0.05)	NS	NS	0.07	0.09	0.15	0.12	0.13
I _F (30 DAS)	0.10	0.30	1.66	2.68	3.01	2.31	1.61
I _P (55 DAS)	0.11	0.28	0.35	1.38	3.30	3.00	2.49
I _O (Drought)	0.12	0.28	0.36	0.90	0.95	0.99	0.86
Sem ±	0.00	0.01	0.02	0.03	0.05	0.04	0.04
C. D (0.05)	NS	NS	0.06	0.08	0.13	0.10	0.11
I _F Water	0.12	0.28	1.32	2.10	2.59	2.07	1.16
Urea	0.09	0.29	1.63	2.52	2.91	2.33	1.57
Urea + Sugar	0.10	0.30	1.54	2.59	3.02	2.35	1.71
Urea + Sugar + K ₂ SO ₄	0.11	0.33	1.99	3.08	3.30	2.42	1.81
Urea + K ₂ SO ₄	0.10	0.30	1.82	3.12	3.24	2.39	1.80
I _P Water	0.17	0.17	0.34	1.27	2.63	2.58	2.13
Urea	0.10	0.27	0.35	1.31	3.23	2.85	2.39
Urea + Sugar	0.10	0.28	0.36	1.36	3.26	2.94	2.54
Urea + Sugar + K ₂ SO ₄	0.11	0.28	0.36	1.54	3.73	3.42	2.75
Urea + K ₂ SO ₄	0.12	0.29	0.36	1.44	3.68	3.23	2.66
I _O Water	0.12	0.27	0.37	0.85	0.94	0.97	0.87
Urea	0.12	0.28	0.36	0.91	0.98	1.03	0.83
Urea + Sugar	0.10	0.28	0.35	0.91	0.96	0.98	0.82
Urea + Sugar + K ₂ SO ₄	0.11	0.28	0.35	0.92	0.94	0.98	0.86
Urea + K ₂ SO ₄	0.13	0.29	0.35	0.91	0.96	1.01	0.90
Sem ±	0.01	0.02	0.05	0.06	0.10	0.08	0.09
C. D (0.05)	NS	NS	0.13	0.17	0.30	0.23	0.25
Control	0.12	0.28	0.37	0.92	0.95	1.00	0.85
Control Vs Rest	0.11	0.29	0.79	1.66	2.42	2.10	1.65
Sem ±	0.01	0.01	0.03	0.04	0.07	0.06	0.06
C. D (0.05)	NS	NS	0.10	0.13	0.22	0.17	0.18
CV %	11.65	9.46	10.49	6.40	7.62	6.78	9.44

Fig. 6 Effect of foliar nutrition and irrigation on stem dry weight (gram per plant) of groundnut.



Urea (0.5%) spray was on par with the stem dry matter production with Urea (0.5%) + Sugar (0.25%) and Urea (0.5%) + K_2SO_4 (0.25%) spray and significantly greater than the water spray. At 60, 75 and 90 DAS foliar spray of Urea (0.5%) and Urea (0.5%) + Sugar (0.25%) are on par with each other and significantly less than the spray of Urea (0.5%) + K_2SO_4 (0.25%) and Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%). At harvest all the foliar nutrition treatments are on par with each other and significantly higher than the water spray with respect to stem dry weight.

Irrigation significantly increased the stem dry matter production over drought conditions. Irrigation at 30 DAS significantly produced highest stem dry matter upto 60 DAS over irrigation at 55 DAS. From 75 DAS irrigation at 55 DAS significantly produced highest stem dry matter over irrigation at 30 DAS and drought treatment.

Foliar spray of nutrients at 20 DAS followed by irrigation at 30 DAS significantly produced higher stem dry matter over water spray at 45, 60 and 75 DAS. At 45 DAS Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) at 20 DAS followed by irrigation at 30 DAS produced highest stem dry matter and it was on par with the stem dry matter produced by the foliar spray of Urea (0.5%) + K_2SO_4 (0.25%) and both these treatments are significantly differing with the stem dry matter produced by Urea

(0.5%) and Urea (0.5%) + Sugar (0.25%) spray. At 90 DAS and at harvest stem dry matter produced by the foliar spray of nutrients was on par with each other and significantly greater than the stem dry matter produced by the water spray.

At 60 DAS stem dry matter produced by the foliar spray of Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) and Urea (0.5%) + K_2SO_4 (0.25%) at 45 DAS followed by irrigation at 55 DAS was significantly greater than the water spray. And remaining foliar sprays given at 45 DAS followed by irrigation are on par with water spray. At 75 and 90 DAS foliar spray of Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) and Urea (0.5%) + K_2SO_4 (0.25%) are on par with each other in stem dry matter production and significantly higher than the other nutrient sprays and water spray. Foliar spray of Urea (0.5%) and Urea (0.5%) + Sugar (0.25%) produced significantly higher stem dry matter than water spray and are on par with each other. At harvest foliar spray of Urea (0.5%) + Sugar (0.25%) significantly produced higher stem dry matter than the Urea (0.5%) spray. Foliar spray of nutrients at 80 DAS under drought stress has no significant effect on stem dry matter production.

4.1.6 Leaf Dry Weight

There was significant difference between the control plants and the rest of the treatment plants with respect to the leaf

Table 7: Effect of nutrient sprays and irrigation on the leaf dry weight (g plant⁻¹) of groundnut.

Treatments	Days after sowing						Harvest
	15	30	45	60	75	90	
Water	0.23	0.43	1.02	1.59	2.21	2.11	1.80
Urea	0.22	0.43	1.15	1.87	2.47	2.31	1.91
Urea + Sugar	0.22	0.43	1.14	1.90	2.49	2.36	1.95
Urea + Sugar + K ₂ SO ₄	0.23	0.46	1.22	2.14	2.97	2.70	2.08
Urea + K ₂ SO ₄	0.22	0.45	1.19	2.07	2.84	2.63	2.06
Sem ±	0.01	0.01	0.04	0.05	0.05	0.04	0.05
C. D (0.05)	NS	NS	0.10	0.13	0.14	0.12	0.14
I _F (30 DAS)	0.22	0.47	1.93	3.28	3.48	2.69	2.03
I _P (55 DAS)	0.23	0.43	0.76	1.47	3.24	3.70	3.02
I _O (Drought)	0.22	0.43	0.75	0.99	1.06	0.88	0.82
Sem ±	0.01	0.01	0.03	0.04	0.04	0.04	0.04
C. D (0.05)	NS	0.04	0.09	0.12	0.12	0.11	0.12
I _F Water	0.23	0.44	1.55	2.62	2.82	2.23	2.03
Urea	0.22	0.45	1.95	3.18	3.29	2.51	1.94
Urea + Sugar	0.22	0.47	1.89	3.22	3.32	2.53	2.02
Urea + Sugar + K ₂ SO ₄	0.23	0.50	2.18	3.81	4.05	3.12	2.06
Urea + K ₂ SO ₄	0.22	0.47	2.05	3.59	3.92	3.05	2.13
I _P Water	0.23	0.42	0.77	1.15	2.75	3.23	2.64
Urea	0.22	0.41	0.76	1.45	3.05	3.56	2.96
Urea + Sugar	0.23	0.43	0.77	1.49	3.12	3.69	2.96
Urea + Sugar + K ₂ SO ₄	0.23	0.44	0.75	1.63	3.79	4.10	3.35
Urea + K ₂ SO ₄	0.23	0.43	0.75	1.61	3.49	3.95	3.20
I _O Water	0.23	0.44	0.73	1.01	1.05	0.88	0.73
Urea	0.23	0.43	0.75	0.99	1.06	0.86	0.82
Urea + Sugar	0.23	0.40	0.76	0.98	1.02	0.87	0.87
Urea + Sugar + K ₂ SO ₄	0.23	0.42	0.74	0.97	1.06	0.88	0.83
Urea + K ₂ SO ₄	0.22	0.44	0.77	1.01	1.10	0.90	0.86
Sem ±	0.01	0.03	0.07	0.09	0.10	0.08	0.09
C. D (0.05)	NS	NS	0.21	0.26	0.28	0.24	0.27
Control	0.21	0.44	0.79	0.96	1.02	0.84	0.84
Control Vs Rest	0.23	0.44	1.15	1.91	2.59	2.42	1.96
Sem ±	0.01	0.02	0.05	0.07	0.07	0.06	0.07
C. D (0.05)	NS	NS	0.15	0.19	0.20	0.18	0.20
CV %	9.26	10.81	10.99	8.41	6.63	6.31	8.68

dry weight (g plant^{-1}) at 45, 60, 75, 90 DAS and at harvest (Table 7 and Fig.7).

Foliar nutrition significantly produced highest leaf dry weight over water spray at 45, 60, 75 and 90 DAS. There was no significant difference between the nutrient sprays at 45 DAS, however significantly highest leaf dry matter was produced by Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) spray. At 60, 75 and 90 DAS significantly highest dry matter was produced by Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) spray and it was on par with the leaf dry weight produced by the Urea (0.5%) + K_2SO_4 (0.25%) spray but these both sprays are significantly superior to the Urea (0.5%) and Urea (0.5%) + Sugar (0.25%) spray. At harvest leaf dry weight with Urea (0.5%) was not significantly differing from the water spray. But leaf dry weight with all other treatments is significantly higher than the water spray.

Irrigation significantly increased leaf dry matter production over drought stress. Irrigation at 30 DAS significantly produced highest leaf dry matter at 45, 60 and 75 DAS over irrigation at 55 DAS and drought stress treatment. At 90 DAS and at harvest, irrigation at 55 DAS significantly resulted in higher leaf dry matter production over irrigation at 30 DAS. Irrigation at 55 DAS produced higher leaf dry matter production over drought

treatment at 60, 75, 90 DAS and at harvest. Among different irrigated treatments lowest leaf dry weight was recorded with drought treatment (I_0).

Foliar spray of nutrients, Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) and Urea (0.5%) + K_2SO_4 (0.25%) at 20 DAS followed by irrigation at 30 DAS significantly produced more leaf dry matter at 45, 60, 75 and 90 DAS over Urea (0.5%) and Urea (0.5%) + Sugar (0.25%). But at harvest where there was no significant difference between the nutrient sprays and water spray. Foliar spray of nutrients at 45 DAS followed by irrigation at 55 DAS significantly increased leaf dry weight over water spray at 60, 75, 90 DAS and at harvest, however there was no significant difference with in the nutrient sprays at 60 DAS. At 75, 90 DAS and at harvest foliar sprays of Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) significantly produced highest leaf dry matter and it was on par with the leaf dry matter produced by the foliar sprays of Urea (0.5%) + K_2SO_4 (0.25%) and these two sprays significantly produced more leaf dry matter than the Urea (0.5%) and Urea (0.5%) + Sugar (0.25%). Foliar sprays at 80 DAS under drought stress did not show any significant effect on leaf dry matter production.

4.1.7 Days to 50 % Flowering

There was no significant difference between the control plants and the rest of the treatment plants with respect to the days to 50% flowering (Table 8 and Fig. 8). Foliar spray alone too did not significantly increase or decrease the days to 50 % flowering. But irrigation was found to significantly decrease the days to 50 % flowering. Irrigation at 30 DAS significantly decreased the days to 50 % flowering (33.5) when compared with drought (I_0) treatment (36.5).

4.2 GROWTH PARAMETERS

4.2.1 Leaf Area Index (LAI)

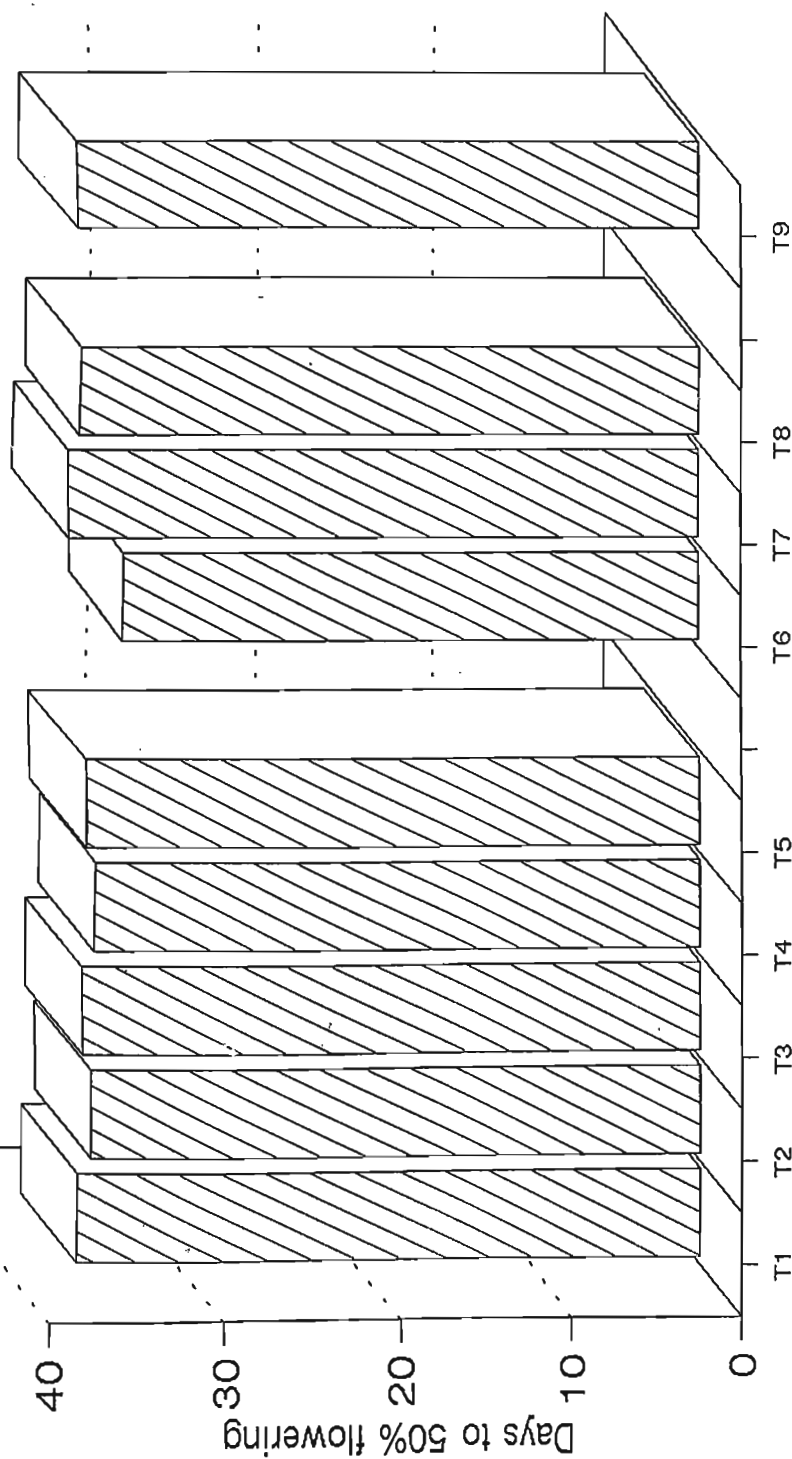
There was significant difference between the control plants and the rest of the treatment plants with respect to the leaf area index at 45, 60, 75, 90 DAS and at harvest (Table 9 and Fig. 9).

Foliar nutrition significantly helped in development of high leaf area index over water spray at 45, 60, 75, 90 DAS and at harvest. There was no significant difference among the nutrient sprays at 45 DAS. At 60, 75 and 90 DAS significantly high leaf area index was produced by Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) spray and it was on par with the leaf area index produced by the Urea (0.5%) + K_2SO_4 (0.25%) spray but these both sprays are significantly superior to the Urea

Table 8: Effect of nutrient sprays and irrigation on the days to 50% flowering of groundnut.

Treatments	Days after sowing
Water	36.1
Urea	35.3
Urea + Sugar	35.8
Urea + Sugar + K ₂ SO ₄	35.1
Urea + K ₂ SO ₄	35.6
Sem ±	0.27
C. D (0.05)	NS
I _F (30 DAS)	33.5
I _P (55 DAS)	36.7
I _O (Drought)	36.5
Sem ±	0.24
C. D (0.05)	0.71
I _F Water	34.7
Urea	33.7
Urea + Sugar	33.3
Urea + Sugar + K ₂ SO ₄	32.7
Urea + K ₂ SO ₄	33.3
I _P Water	37.0
Urea	36.7
Urea + Sugar	37.3
Urea + Sugar + K ₂ SO ₄	36.7
Urea + K ₂ SO ₄	35.7
I _O Water	36.7
Urea	35.7
Urea + Sugar	36.7
Urea + Sugar + K ₂ SO ₄	36.0
Urea + K ₂ SO ₄	37.7
Sem ±	0.55
C. D (0.05)	NS
Control	36.3
Control Vs Rest	35.6
Sem ±	0.40
C. D (0.05)	NS
CV %	2.7

Fig.8 Effect of nutrient sprays and irrigation on the days to 50% flowering of groundnut.



T1: Water
 T2: Urea
 T3: Urea + Sugar
 T4: Urea + Sugar + Potassium Sulphate
 T5: Urea + Potassium Sulphate
 T6: Irrigation at flowering stage
 T7: Irrigation at pegging stage
 T8: Drought stress
 T9: Control

(0.5%) and Urea (0.5%) + Sugar (0.25%) spray. At harvest LAI with Urea (0.5%) was not significantly differing from the water spray, whereas remaining treatments are significantly higher than the water spray.

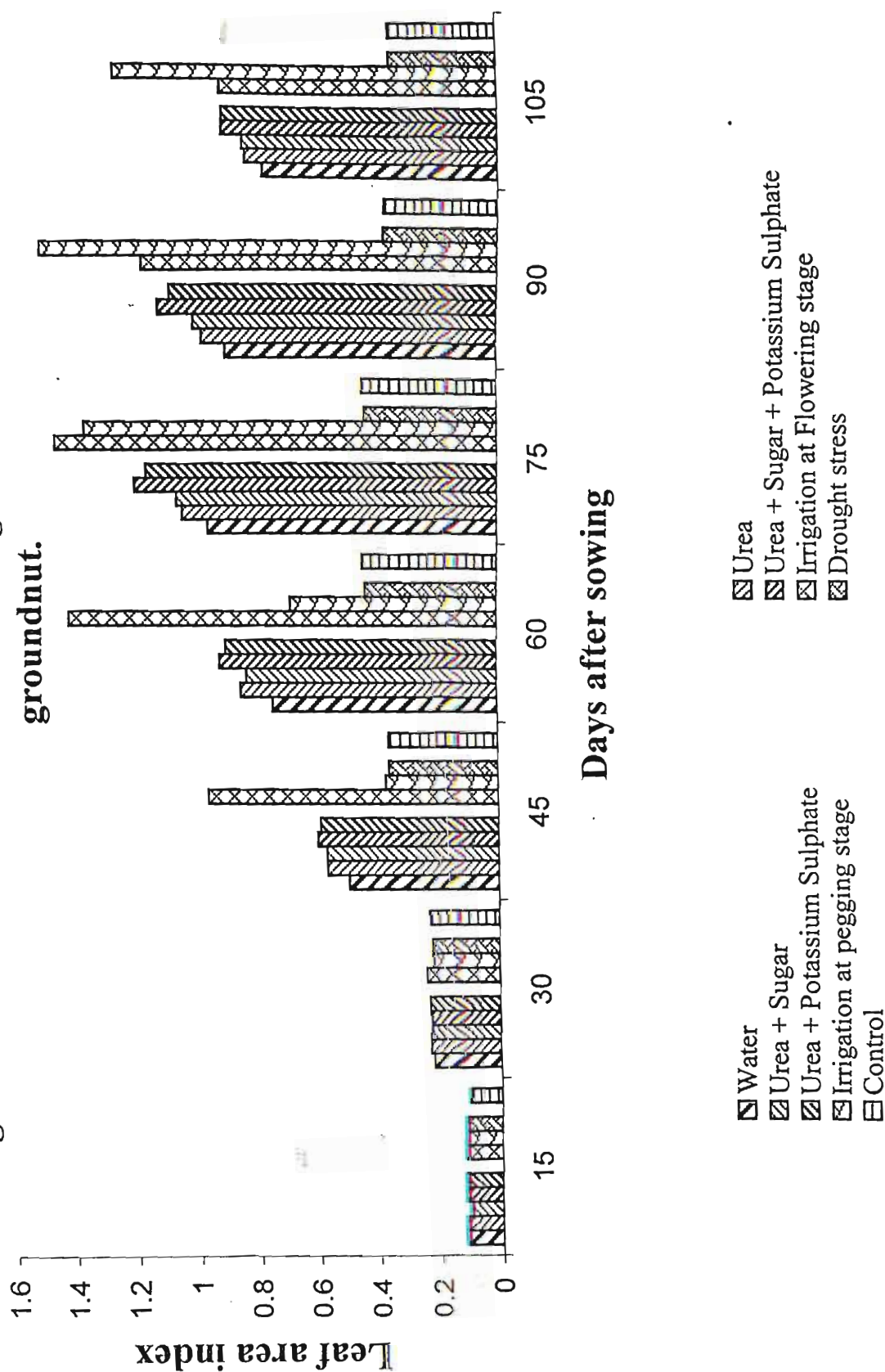
Irrigation significantly increased leaf area index over drought. Irrigation at 30 DAS significantly produced highest leaf area index than irrigation at 55 DAS and drought treatment at 45, 60 and 75 DAS. At 90 DAS and at harvest, irrigation at 55 DAS significantly resulted in higher leaf area index over irrigation at 30 DAS. Irrigation at 55 DAS produced higher leaf area index over drought treatment at 60, 75, 90 DAS and at harvest. Among all the treatments lowest leaf area index was recorded with drought stress treatment (I_0).

Foliar spray of nutrients, Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) and Urea (0.5%) + K_2SO_4 (0.25%) at 20 DAS followed by irrigation at 30 DAS significantly showed high leaf area index at 45, 60, 75 and 90 DAS over Urea (0.5%) and Urea (0.5%) + Sugar (0.25%), unlike at harvest where there was no significant difference between the nutrient sprays and the water spray. Foliar spray of nutrients at 45 DAS followed by irrigation at 55 DAS significantly increased leaf area index over water spray at 60, 75, 90 DAS and at harvest. However, there was no significant difference with in the nutrient sprays at 60

Table 9: Effect of nutrient sprays and irrigation on the leaf area index of groundnut.

Treatments	Days after sowing						Harvest
	15	30	45	60	75	90	
Water	0.12	0.22	0.49	0.74	0.95	0.90	0.77
Urea	0.12	0.23	0.56	0.84	1.04	0.98	0.83
Urea + Sugar	0.11	0.23	0.56	0.83	1.06	1.01	0.84
Urea + Sugar + K_2SO_4	0.12	0.23	0.59	0.92	1.20	1.12	0.91
Urea + K_2SO_4	0.12	0.23	0.58	0.89	1.18	1.09	0.91
Sem $\pm$	0.003	0.007	0.014	0.017	0.02	0.02	0.02
C. D (0.05)	NS	NS	0.040	0.051	0.07	0.06	0.06
I _F (30 DAS)	0.12	0.24	0.96	1.43	1.47	1.18	0.92
I _P (55 DAS)	0.12	0.22	0.36	0.68	1.37	1.52	1.27
I _O (Drought)	0.12	0.22	0.35	0.42	0.42	0.36	0.36
Sem $\pm$	0.002	0.007	0.012	0.016	0.02	0.02	0.02
C. D (0.05)	NS	NS	0.036	0.045	0.06	0.05	0.06
I _F Water	0.12	0.22	0.79	1.21	1.25	1.01	0.89
Urea	0.12	0.24	0.98	1.41	1.38	1.13	0.91
Urea + Sugar	0.11	0.23	0.96	1.40	1.43	1.16	0.92
Urea + Sugar + K_2SO_4	0.12	0.26	1.07	1.58	1.65	1.31	0.95
Urea + K_2SO_4	0.11	0.26	1.02	1.54	1.63	1.28	0.96
I _P Water	0.12	0.22	0.35	0.58	1.19	1.33	1.08
Urea	0.12	0.22	0.35	0.69	1.33	1.45	1.24
Urea + Sugar	0.11	0.22	0.36	0.67	1.34	1.50	1.22
Urea + Sugar + K_2SO_4	0.12	0.22	0.34	0.74	1.54	1.68	1.42
Urea + K_2SO_4	0.12	0.22	0.37	0.72	1.48	1.63	1.40
I _O Water	0.12	0.21	0.33	0.42	0.42	0.36	0.34
Urea	0.12	0.23	0.35	0.42	0.42	0.36	0.35
Urea + Sugar	0.12	0.23	0.35	0.41	0.42	0.37	0.38
Urea + Sugar + K_2SO_4	0.11	0.20	0.35	0.43	0.43	0.37	0.36
Urea + K_2SO_4	0.12	0.22	0.35	0.42	0.42	0.36	0.38
Sem $\pm$	0.005	0.015	0.028	0.035	0.05	0.04	0.04
C. D (0.05)	NS	NS	0.080	0.101	0.13	0.11	0.13
Control	0.11	0.23	0.35	0.42	0.42	0.35	0.36
Control Vs Rest	0.12	0.23	0.56	0.84	1.09	1.02	0.85
Sem $\pm$	0.004	0.011	0.020	0.026	0.03	0.03	0.03
C. D (0.05)	NS	NS	0.058	0.074	0.10	0.08	0.09
CV %	8.14	11.16	8.82	7.42	7.46	6.95	9.15

Fig. 9 Effect of foliar nutrition and irrigation on leaf area index of groundnut.



DAS. At 75, 90 DAS and at harvest foliar sprays of Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) significantly developed highest leaf area index and it was on par with the leaf area index observed with the foliar sprays of Urea (0.5%) + K_2SO_4 (0.25%) and these two sprays significantly showed high leaf area index than the Urea (0.5%) and Urea (0.5%)+ Sugar (0.25%). Foliar sprays at 80 DAS under drought stress did not show any significant effect on leaf area index.

4.2.2 Specific Leaf Weight (SLW) ($mg\ cm^{-2}$)

There was no significant difference between the control plants and the rest of the treatment plants at 30, 45, 60, 75, 90 DAS and at harvest (Table 10 and Fig. 10) with respect to the specific leaf weight

In general specific leaf weight was maximum at 75 DAS with irrigation at 30 DAS (I_F) or when grown with receding soil moisture conditions (I_o). In irrigation at 55 DAS (I_P) treatment specific leaf weight was maximum at 90 DAS.

4.2.3 Relative Growth Rate (RGR) ($mg\ g^{-1}\ d^{-1}$)

There was significant difference between the control plots and rest of the treatments between 30-45, 45-60, 60-75 DAS, 75-90 DAS and 90 DAS to harvest (Table 11 and Fig. 11).

Table 10: Effect of nutrient sprays and irrigation on the specific leaf weight (mg cm^{-2}) of groundnut.

Treatments	Days after sowing						Harvest
	15	30	45	60	75	90	
Water	6.57	6.82	7.11	7.29	7.92	7.91	7.67
Urea	6.25	6.37	6.96	7.47	8.03	7.94	7.68
Urea + Sugar	6.53	6.39	6.93	7.70	7.92	7.82	7.74
Urea + Sugar + K_2SO_4	6.55	6.76	7.10	7.62	8.22	8.03	7.58
Urea + K_2SO_4	6.42	6.41	6.93	7.72	8.20	8.11	7.55
Sem $\pm$	0.21	0.30	0.23	0.18	0.21	0.25	0.22
C. D (0.05)	NS	NS	NS	NS	NS	NS	NS
I _F (30 DAS)	6.51	6.46	6.67	7.66	7.92	7.63	7.39
I _P (55 DAS)	6.48	6.54	7.14	7.18	7.88	8.16	7.96
I _O (Drought)	6.41	6.64	7.21	7.83	8.38	8.10	7.58
Sem $\pm$	0.19	0.27	0.21	0.16	0.19	0.22	0.20
C. D (0.05)	NS	NS	NS	NS	NS	NS	NS
I _F Water	6.66	6.70	6.63	7.23	7.61	7.43	7.62
Urea	6.28	6.26	6.65	7.52	7.95	7.47	7.20
Urea + Sugar	6.46	6.64	6.59	7.74	7.77	7.32	7.37
Urea + Sugar + K_2SO_4	6.54	6.57	6.80	8.04	8.21	7.95	7.25
Urea + K_2SO_4	6.61	6.16	6.68	7.78	8.04	7.99	7.53
I _P Water	6.54	6.59	7.32	6.64	7.83	8.16	8.13
Urea	6.05	6.47	7.18	7.03	7.71	8.17	8.03
Urea + Sugar	6.80	6.63	7.06	7.49	7.77	8.25	8.13
Urea + Sugar + K_2SO_4	6.54	6.59	7.34	7.33	8.23	8.14	7.87
Urea + K_2SO_4	6.45	6.43	6.78	7.42	7.86	8.05	7.65
I _O Water	6.51	7.16	7.38	7.99	8.32	8.13	7.25
Urea	6.41	6.37	7.04	7.86	8.44	8.18	7.82
Urea + Sugar	6.32	5.90	7.13	7.89	8.22	7.90	7.72
Urea + Sugar + K_2SO_4	6.57	7.14	7.16	7.50	8.21	7.99	7.63
Urea + K_2SO_4	6.22	6.65	7.34	7.94	8.70	8.29	7.48
Sem $\pm$	0.42	0.61	0.47	0.37	0.43	0.50	0.45
C. D (0.05)	NS	NS	NS	NS	NS	NS	NS
Control	6.40	6.27	7.55	7.64	8.01	7.97	7.91
Control Vs Rest	6.46	6.55	7.00	7.56	8.06	7.96	7.65
Sem $\pm$	0.31	0.44	0.34	0.27	0.31	0.36	0.33
C. D (0.05)	NS	NS	NS	NS	NS	NS	NS
CV %	11.32	16.11	11.53	8.39	9.18	10.83	10.15

Fig. 10 Effect of foliar nutrition and irrigation on specific leaf weight
(mg cm^{-2}) of groundnut.

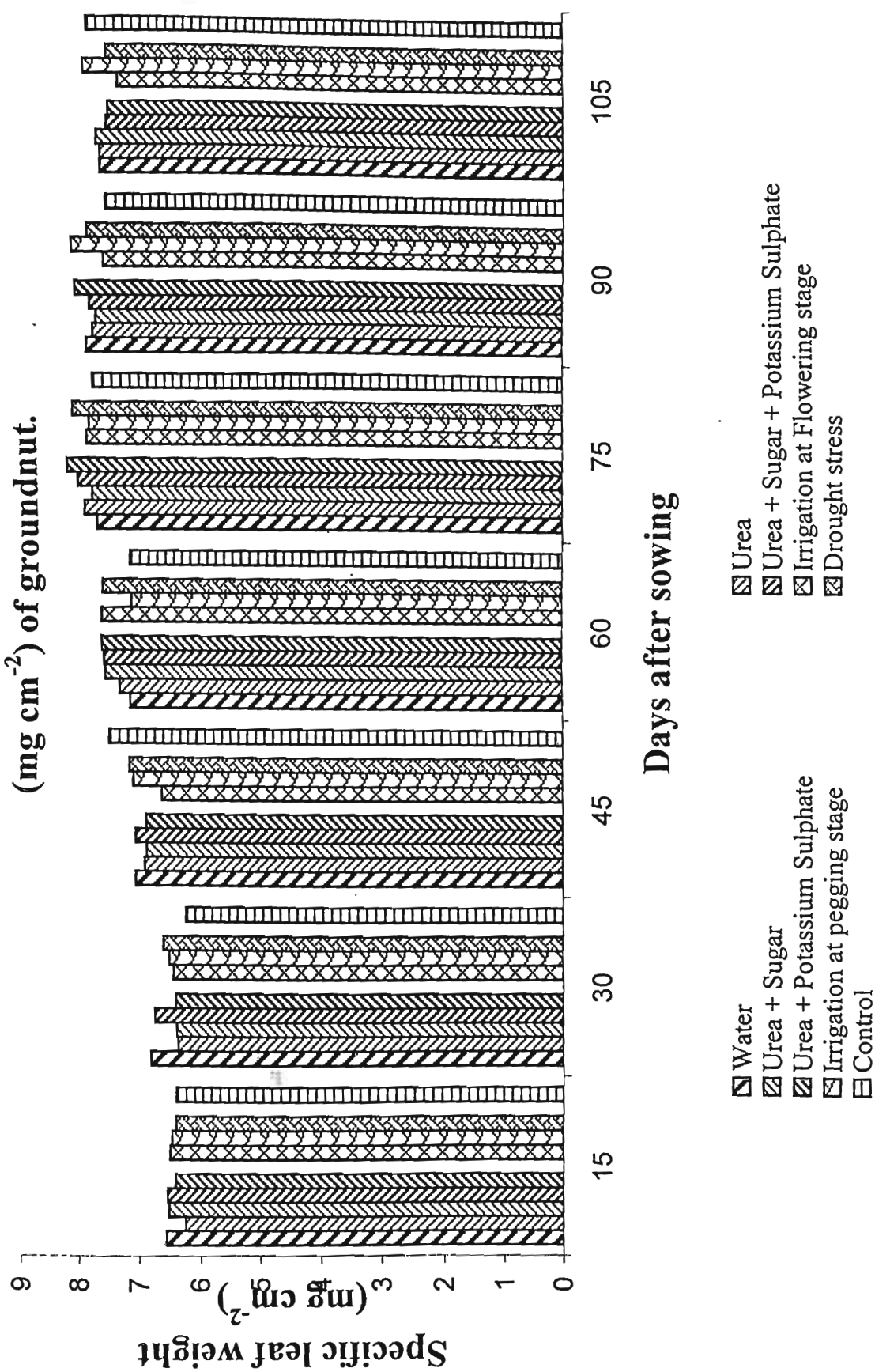


Table 11: Effect of nutrient sprays and irrigation on the relative growth rate ($\text{mg g}^{-1} \text{d}^{-1}$) of groundnut.

Treatments	Days after sowing					
	15-30	30-45	45-60	60-75	75-90	90-harvest
Water	48.65	50.19	40.18	22.20	-4.99	-14.26
Urea	51.98	55.71	42.45	21.81	-6.70	-14.25
Urea + Sugar	52.81	54.40	44.17	20.87	-6.57	-12.04
Urea + Sugar + K_2SO_4	52.64	55.47	46.70	21.85	-7.94	-14.73
Urea + K_2SO_4	52.22	54.79	46.77	21.93	-7.73	-13.65
Sem $\pm$	1.89	1.63	1.68	0.58	0.32	0.68
C. D (0.05)	NS	NS	NS	NS	0.93	NS
I_F (30 DAS)	56.27	102.41	33.92	5.86	-17.30	-21.08
I_P (55 DAS)	49.79	30.09	62.41	55.26	1.82	-13.01
I_O (Drought)	48.92	29.83	35.82	4.08	-4.87	-7.27
Sem $\pm$	1.69	1.46	1.50	0.52	0.29	0.61
C. D (0.05)	4.88	4.22	4.34	1.49	0.83	1.77
I_F Water	48.81	92.50	33.15	9.14	-15.29	-20.02
Urea	57.13	104.76	30.88	5.82	-16.50	-21.68
Urea + Sugar	58.67	99.89	35.24	5.81	-17.45	-17.99
Urea + Sugar + K_2SO_4	58.96	107.81	33.54	4.18	-18.91	-23.98
Urea + K_2SO_4	57.78	107.11	36.80	4.33	-18.35	-21.72
I_P Water	48.18	29.15	52.31	53.26	5.09	-13.03
Urea	51.06	32.48	60.78	54.71	1.37	-12.12
Urea + Sugar	51.35	30.74	61.69	53.69	2.52	-12.47
Urea + Sugar + K_2SO_4	49.68	29.51	69.67	57.64	-0.01	-13.97
Urea + K_2SO_4	48.68	28.58	67.62	56.99	0.11	-13.46
I_O Water	48.96	28.91	35.08	4.19	-4.76	-9.71
Urea	47.74	29.88	35.69	4.89	-4.95	-8.94
Urea + Sugar	48.40	32.59	35.57	3.12	-4.77	-5.66
Urea + Sugar + K_2SO_4	49.29	29.09	36.88	3.74	-4.90	-6.24
Urea + K_2SO_4	50.21	28.67	35.88	4.45	-4.95	-5.78
Sem $\pm$	3.78	3.27	3.36	1.15	0.64	1.37
C. D (0.05)	NS	NS	NS	3.33	1.86	NS
Control	51.78	31.67	32.02	3.15	-4.18	-5.52
Control Vs Rest	51.66	54.11	44.05	21.73	-6.78	-13.79
Sem $\pm$	2.76	2.39	2.46	0.84	0.47	1.00
C. D (0.05)	NS	6.89	7.09	2.43	1.36	2.89
CV %	12.68	10.74	13.45	9.70	-16.81	-17.88

Relative growth rate was not significantly influenced by foliar nutrition except between 75-90 DAS.

Effect of irrigation on relative growth rate was significant between 15-30 DAS, 30-45 DAS, 45-60 DAS, 60-75 DAS 75-90 DAS and 90 DAS to harvest. Irrigation at 30 DAS significantly increased the relative growth rate from 30-45 DAS (102.42) and 60-75 DAS (6.00) over drought treatment and was on par with drought treatment between 45-60 DAS (33.82). Relative growth rate was maximum between 30-45 DAS (102.41) in irrigation at 30 DAS whereas, in irrigation at 55 DAS (62.41) and drought treatment (35.82) RGR was maximum between 45-60 DAS.

Relative growth rate was maximum between 60-75 DAS with the foliar spray of Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) (57.64) and was on par with RGR of Urea (0.5%) + K_2SO_4 (0.25%) spray (56.99) at 45 DAS followed by irrigation at 55 DAS.

4.3 PHYSIOLOGICAL PARAMETERS

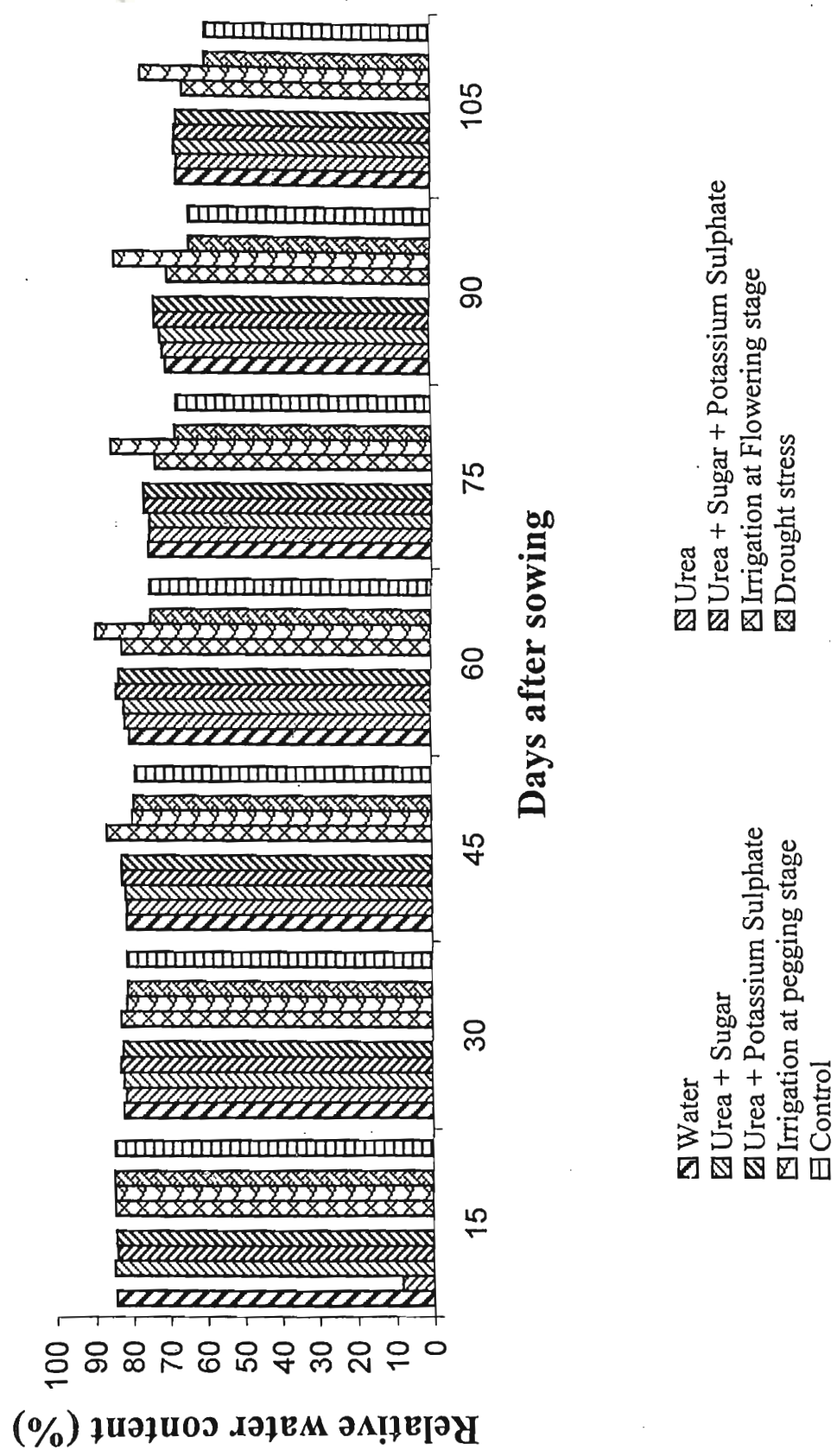
4.3.1 Relative Water Content

There was significant difference between the control plants and the rest of the treatment plants with respect to the relative water content (%) at 45, 60, 75, 90 DAS and at harvest (Table 12 and Fig. 12).

Table 12: Effect of nutrient sprays and irrigation on the leaf relative water content (%) of groundnut.

Treatments	Days after sowing						Harvest
	15	30	45	60	75	90	
Water	84.7	82.0	81.5	80.4	75.4	70.2	66.4
Urea	84.8	81.3	81.3	81.6	75.2	71.0	66.3
Urea + Sugar	85.1	82.0	81.6	81.8	75.2	71.6	67.0
Urea + Sugar + K ₂ SO ₄	84.2	82.9	82.5	83.8	76.7	72.9	66.9
Urea + K ₂ SO ₄	84.4	82.4	82.5	83.0	76.8	72.8	66.5
Sem ±	0.8	0.6	0.3	0.5	0.4	0.4	0.5
C. D (0.05)	NS	NS	NS	1.5	1.1	1.1	NS
I _F (30 DAS)	84.7	83.2	86.5	82.4	73.7	69.0	65.0
I _P (55 DAS)	84.5	81.7	79.8	89.4	85.5	83.1	75.8
I _O (Drought)	84.7	81.5	79.3	74.6	68.3	63.0	59.1
Sem ±	0.7	0.6	0.3	0.5	0.3	0.3	0.5
C. D (0.05)	NS	NS	0.9	1.3	1.0	1.0	1.4
I _F Water	84.5	82.4	84.4	80.6	72.9	67.9	64.4
Urea	84.3	81.3	85.3	81.4	72.7	68.3	64.8
Urea + Sugar	85.1	82.2	85.7	81.6	72.2	68.8	65.7
Urea + Sugar + K ₂ SO ₄	84.9	85.3	88.9	84.4	75.3	69.5	65.2
Urea + K ₂ SO ₄	84.8	84.8	88.2	83.7	75.5	70.7	65.0
I _P Water	84.4	81.2	79.6	86.9	84.4	80.6	75.3
Urea	85.4	81.9	79.9	88.0	85.0	82.6	75.3
Urea + Sugar	84.4	82.1	80.4	89.5	84.4	82.6	75.3
Urea + Sugar + K ₂ SO ₄	83.2	82.0	79.4	91.7	87.2	85.7	77.2
Urea + K ₂ SO ₄	85.0	81.1	79.9	90.8	86.7	84.1	76.0
I _O Water	85.3	82.5	80.6	73.8	68.8	62.1	59.6
Urea	84.5	80.6	78.8	75.2	68.1	62.2	58.8
Urea + Sugar	85.8	81.6	78.7	74.2	69.0	63.4	59.9
Urea + Sugar + K ₂ SO ₄	84.4	81.5	79.1	75.5	67.5	63.6	58.5
Urea + K ₂ SO ₄	83.3	81.3	79.5	74.5	68.2	63.7	58.6
Sem ±	1.6	1.3	0.7	1.0	0.8	0.8	1.1
C. D (0.05)	NS	NS	1.9	NS	NS	NS	NS
Control	84.4	81.7	78.9	75.0	67.8	63.1	59.1
Control Vs Rest	84.6	82.1	81.9	82.1	75.9	71.7	66.6
Sem ±	1.2	0.9	0.5	0.8	0.6	0.6	0.8
C. D (0.05)	NS	NS	1.4	2.2	1.6	1.6	2.3
CV %	3.4	2.7	1.4	2.2	1.8	1.8	2.8

Fig. 12 Effect of foliar nutrition and irrigation on relative water content (%) of groundnut.



Foliar nutrition significantly increased relative water content over water spray at 60, 75 and 90 DAS. Significantly higher relative water content was observed with Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) spray and it was on par with the relative water content observed with the Urea (0.5%) + K_2SO_4 (0.25%) spray however, both these sprays are significantly superior to water spray. Whereas Urea (0.5%) and Urea (0.5%) + Sugar (0.25%) are on par with water spray.

Irrigation significantly increased relative water content over drought at 45, 60, 75, 90 DAS and at harvest. Irrigation at 30 DAS significantly showed higher relative water content over drought treatment at 45, 60, 75, 90 DAS and at harvest. Irrigation at 55 DAS significantly maintained more relative water content at 60, 75, 90 DAS and at harvest than irrigation at 30 DAS and drought conditions. Among all the treatments lowest relative water content was recorded with drought treatment (I_0).

Foliar spray of nutrients, Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) at 20 DAS followed by irrigation at 30 DAS significantly increased relative water content at 45 DAS and it was par with the foliar sprays of Urea (0.5%) + K_2SO_4 (0.25%) and these two sprays significantly showed more relative water content than the Urea (0.5%) and Urea (0.5%) + Sugar (0.25%)

and water spray. Foliar sprays at 80 DAS under drought stress did not show any significant effect on relative water content.

4.3.2 Stomatal Resistance

There was significant difference between the control plants and the rest of the treatment plants with respect to the stomatal resistance ($S\text{ cm}^{-1}$) at 45, 60, 75, 90 DAS and at harvest (Table 13 and Fig. 13).

Foliar nutrition significantly increased stomatal resistance over water spray at 45, 60, 75 and 90 DAS and at harvest. Significantly highest stomatal resistance was developed with Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) spray and it was on par with the stomatal resistance with Urea (0.5%) + K_2SO_4 (0.25%) spray and both sprays are significantly superior to water spray. Stomatal resistance with Urea (0.5%) and Urea (0.5%) + Sugar (0.25%) are on par with water spray.

Irrigation significantly decreased stomatal resistance over drought at 45, 60, 75 and 90 DAS and at harvest. Irrigation at 30 DAS significantly showed lower stomatal resistance over drought treatment at 45, 60, 75 and 90 DAS and at harvest. Irrigation at 55 DAS significantly maintained lower stomatal resistance at 60, 75, 90 DAS and at harvest than irrigation at 30 DAS and drought treatment. Among all the treatments highest

Table 13: Effect of nutrient sprays and irrigation on the stomatal resistance ($S\text{ cm}^{-1}$) of groundnut.

Treatments	Days after sowing						Harvest
	15	30	45	60	75	90	
Water	2.48	5.44	6.83	8.70	11.70	17.16	20.17
Urea	2.57	5.62	6.88	8.64	11.22	17.84	20.14
Urea + Sugar	2.44	5.41	6.77	8.87	11.61	17.58	20.04
Urea + Sugar + K_2SO_4	2.34	5.93	7.13	9.97	12.74	19.69	22.34
Urea + K_2SO_4	2.40	5.93	7.31	9.86	12.54	20.78	22.16
Sem $\pm$	0.07	0.17	0.09	0.14	0.27	0.47	0.56
C. D (0.05)	NS	NS	0.25	0.40	0.77	1.37	1.61
I_F (30 DAS)	2.49	5.85	4.00	7.85	11.31	19.43	20.95
I_P (55 DAS)	2.45	5.57	8.50	4.61	6.82	13.97	18.07
I_O (Drought)	2.41	5.59	8.45	15.17	17.77	22.43	23.89
Sem $\pm$	0.06	0.15	0.08	0.13	0.24	0.42	0.50
C. D (0.05)	NS	NS	0.22	0.36	0.69	1.23	1.44
I_F Water	2.57	5.50	3.57	6.47	10.70	19.67	21.03
Urea	2.47	5.60	3.60	7.17	10.33	19.53	19.07
Urea + Sugar	2.33	5.37	3.50	6.87	10.93	18.77	20.80
Urea + Sugar + K_2SO_4	2.40	6.30	4.50	9.50	12.37	19.13	22.13
Urea + K_2SO_4	2.67	6.47	4.83	9.23	12.20	20.03	21.73
I_P Water	2.53	5.73	8.49	4.20	6.13	10.63	15.53
Urea	2.50	5.63	8.67	3.93	6.17	12.77	16.13
Urea + Sugar	2.57	4.97	8.53	4.27	5.83	12.47	17.07
Urea + Sugar + K_2SO_4	2.37	5.87	8.27	5.20	8.13	16.33	20.03
Urea + K_2SO_4	2.27	5.63	8.53	5.43	7.83	17.63	21.60
I_O Water	2.33	5.10	8.43	15.43	18.27	21.17	23.93
Urea	2.73	5.63	8.37	14.83	17.17	21.23	25.23
Urea + Sugar	2.43	5.90	8.27	15.47	18.07	21.50	22.27
Urea + Sugar + K_2SO_4	2.27	5.63	8.63	15.20	17.73	23.60	24.87
Urea + K_2SO_4	2.27	5.70	8.57	14.90	17.60	24.67	23.13
Sem $\pm$	0.14	0.33	0.17	0.28	0.53	0.95	1.12
C. D (0.05)	NS	NS	0.50	0.81	NS	NS	NS
Control	2.30	5.77	8.60	15.27	17.57	21.53	24.57
Control Vs Rest	2.45	5.67	6.98	9.21	11.96	18.61	20.97
Sem $\pm$	0.10	0.24	0.13	0.20	0.39	0.69	0.82
C. D (0.05)	NS	NS	0.36	0.59	1.13	2.00	2.36
CV %	9.87	10.16	4.20	5.05	7.52	8.75	9.14

stomatal resistance was recorded with drought treatment (I_0) (23.89).

Foliar spray of nutrients, Urea (0.5%) + K_2SO_4 (0.25%) at 20 DAS followed by irrigation at 30 DAS significantly recorded higher stomatal resistance at 45 and 60 DAS and it was par with the foliar sprays of Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%). However, at 60 DAS high stomatal resistance was recorded with Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) spray and these two sprays significantly increased stomatal resistance over Urea (0.5%) and Urea (0.5%) + Sugar (0.25%) and water spray. Foliar spray of Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) at 45 DAS followed by irrigation at 55 DAS significantly increased stomatal resistance over other foliar nutrients spray, but was on par with Urea (0.5%) + K_2SO_4 (0.25%) spray. Foliar sprays at 80 DAS under drought stress did not show any significant effect on stomatal resistance.

4.3.3 Leaf Temperature

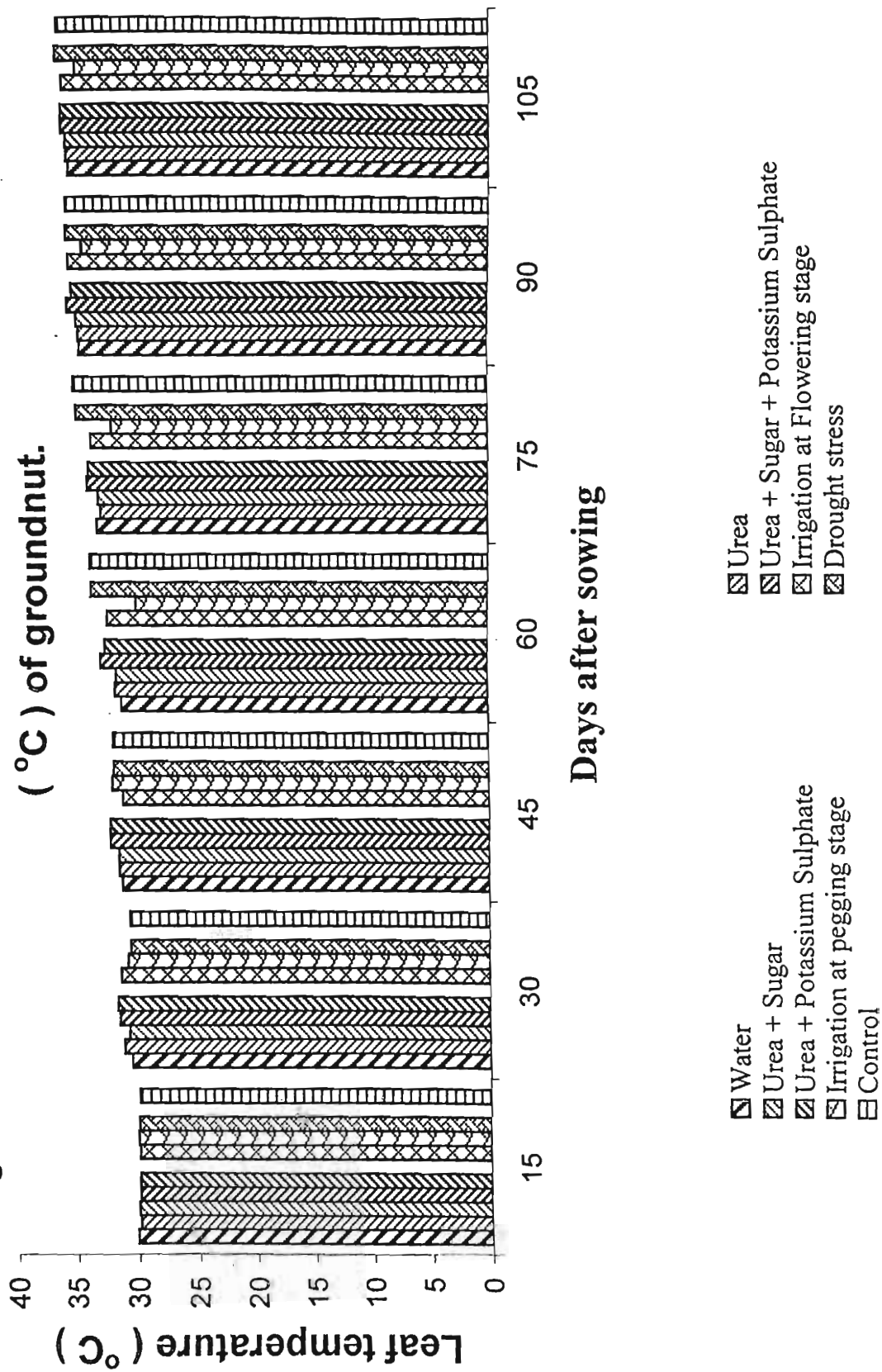
There was significant difference between the control plants and the rest of the treatment plants with respect to the leaf temperature ($^{\circ}C$) only at 60 and 75 DAS (Table 14 and Fig. 14).

Foliar nutrition significantly increased leaf temperature over water spray at 60, 75 and 90 DAS. Significantly

Table 14: Effect of nutrient sprays and irrigation on the leaf temperature ($^{\circ}\text{C}$) of groundnut.

Treatments	Days after sowing						Harvest
	15	30	45	60	75	90	
Water	30.1	30.4	31.3	31.4	33.4	34.7	35.4
Urea	29.9	31.0	31.5	31.9	33.1	34.8	35.6
Urea + Sugar	30.0	30.6	31.5	31.8	33.3	35.0	35.7
Urea + Sugar + K_2SO_4	29.9	31.4	32.2	33.1	34.2	35.7	36.1
Urea + K_2SO_4	29.9	31.6	32.2	32.7	34.1	35.3	36.1
Sem $\pm$	0.3	0.3	0.2	0.3	0.2	0.2	0.3
C. D (0.05)	NS	NS	NS	0.8	0.6	0.6	NS
I_F (30 DAS)	29.9	31.4	31.2	32.5	33.8	35.5	36.0
I_P (55 DAS)	30.0	30.9	32.1	30.1	32.1	34.3	34.8
I_O (Drought)	29.9	30.7	32.0	33.9	35.0	35.6	36.5
Sem $\pm$	0.3	0.3	0.2	0.3	0.2	0.2	0.3
C. D (0.05)	NS	NS	0.5	0.8	0.5	0.6	0.7
I_F Water	29.9	30.1	29.8	31.4	33.2	34.5	35.6
Urea	29.8	31.5	30.6	31.9	33.3	35.1	35.9
Urea + Sugar	30.1	30.3	30.3	31.6	33.3	35.4	36.0
Urea + Sugar + K_2SO_4	29.8	32.1	32.4	34.0	34.7	36.6	36.1
Urea + K_2SO_4	30.0	33.3	32.6	33.7	34.5	35.8	36.5
I_P Water	30.2	30.6	32.0	29.7	31.7	34.0	34.3
Urea	29.8	30.9	32.3	30.0	31.7	33.9	34.3
Urea + Sugar	30.3	30.8	31.9	29.7	31.3	33.9	34.4
Urea + Sugar + K_2SO_4	30.1	31.2	32.2	30.8	32.9	35.0	35.4
Urea + K_2SO_4	29.9	30.7	32.0	30.5	32.9	34.5	35.7
I_O Water	30.1	30.6	32.2	33.2	35.3	35.5	36.4
Urea	30.1	30.6	31.7	33.8	34.3	35.4	36.5
Urea + Sugar	29.7	30.8	32.3	34.2	35.4	35.8	36.8
Urea + Sugar + K_2SO_4	29.9	30.8	32.0	34.5	35.1	35.6	36.9
Urea + K_2SO_4	29.9	30.9	31.9	34.0	35.0	35.8	36.1
Sem $\pm$	0.7	0.6	0.4	0.6	0.4	0.4	0.6
C. D (0.05)	NS	NS	1.2	NS	NS	NS	NS
Control	29.8	30.8	32.1	34.0	35.2	35.6	36.3
Control Vs Rest	30.0	31.0	31.8	32.2	33.6	35.1	35.8
Sem $\pm$	0.5	0.4	0.3	0.4	0.3	0.3	0.4
C. D (0.05)	NS	NS	NS	1.2	0.9	NS	NS
CV %	3.9	3.2	2.3	3.1	2.2	2.1	2.8

Fig. 14 Effect of foliar nutrition and irrigation on leaf temperature



highest leaf temperature was observed with Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) spray and it was on par with the leaf temperature with Urea (0.5%) + K_2SO_4 (0.25%) spray, but both these sprays are significantly superior to water spray. Whereas temperature recorded with Urea (0.5%) and Urea (0.5%) + Sugar (0.25%) are on par with water spray.

Irrigation significantly decreased leaf temperature over drought at 45, 60, 75, 90 DAS and at harvest. Irrigation at 30 DAS significantly lowered leaf temperature over drought treatment at 45, 60 and 75 DAS. At 90 DAS and at harvest leaf temperature recorded with irrigation at 30 DAS was on par with the leaf temperature with drought conditions. Irrigation at 55 DAS significantly maintained lower leaf temperature at 60, 75, 90 DAS and at harvest than irrigation at 30 DAS and drought treatment. Among all the treatments highest leaf temperature was recorded with drought treatment (I_0) (36.5).

Foliar spray of nutrients, Urea (0.5%) + K_2SO_4 (0.25%) at 20 DAS followed by irrigation at 30 DAS significantly recorded higher leaf temperature at 45 DAS and it was par with the foliar sprays of Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) and these two sprays showed significant increase leaf temperature over Urea (0.5%) and Urea (0.5%) + Sugar (0.25%)

and water spray. Foliar sprays at 80 DAS under drought stress did not show any significant effect on leaf temperature.

4.4 BIOCHEMICAL PARAMETER

4.4.1 Proline Content

There was significant difference between the control plants and the rest of the treatment plants with respect to the leaf proline content ($\mu\text{g g}^{-1}$ fresh weight) at 55 DAS (Table 15 and Fig. 15).

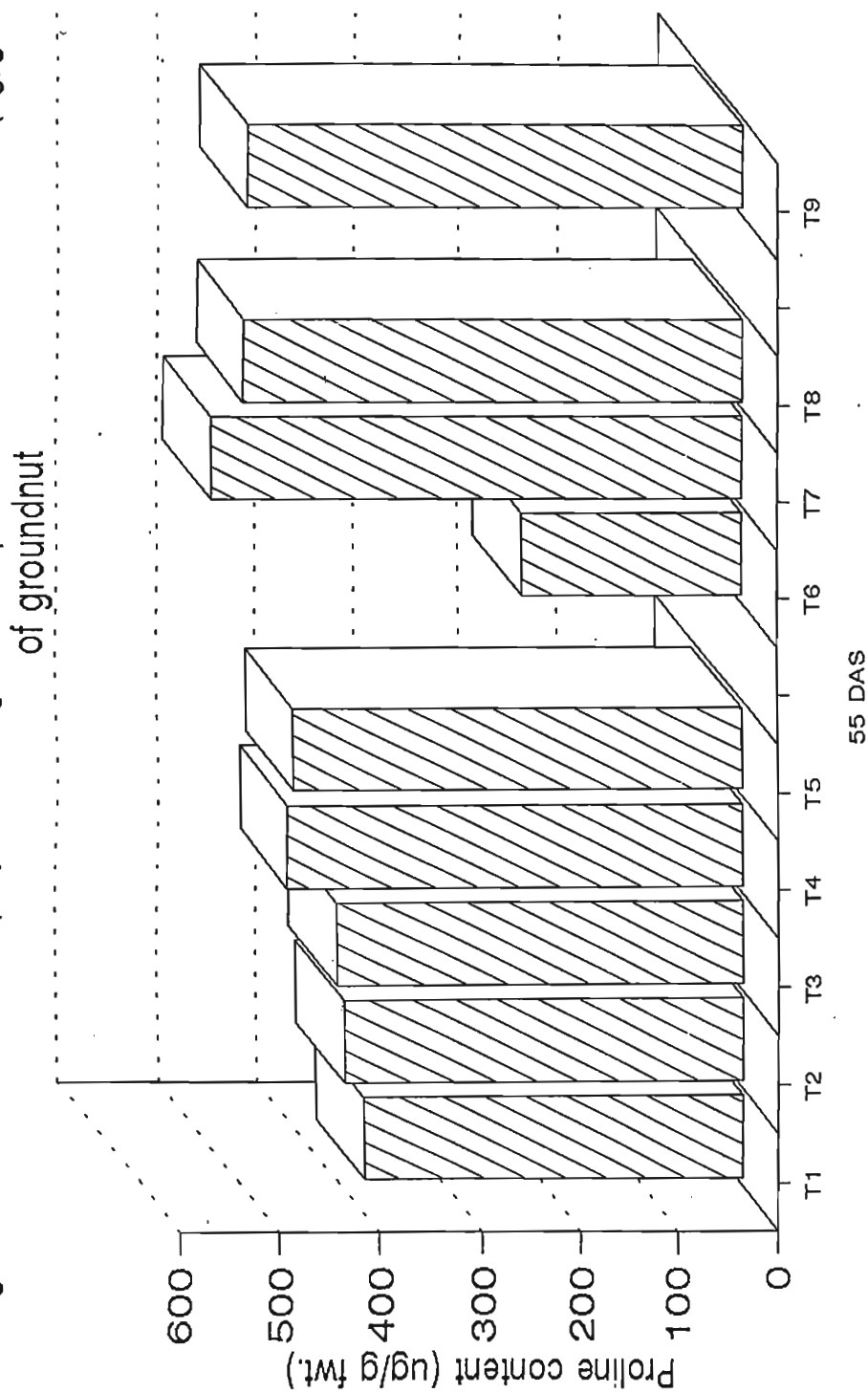
Foliar spray of Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) (451.37) and Urea (0.5%) + K_2SO_4 (0.25%) (444.88) significantly increased the proline content in the leaves over water spray (376.77). Irrigation at 30 DAS significantly decreased the proline content in the leaves (219.57). High proline content (527.96) was observed in the leaves in case of irrigation at 55 DAS as foliar spray was given earlier at 45 DAS.

Irrigation at 30 DAS after spraying of Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) at 20 DAS significantly increased (273.43) the leaf proline content at 55 DAS over water spray (159.92). Foliar spray of Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) (575.35) and Urea (0.5%) + K_2SO_4 (0.25%) (599.47) at 45 DAS without providing irrigation at 55 DAS after sowing significantly increased the proline content at 55 DAS over all

Table 15: Effect of nutrient sprays and irrigation on the leaf proline content ($\mu\text{g g}^{-1}$ fresh weight) of groundnut.

Treatments	Proline Content
Water	376.77
Urea	395.61
Urea + Sugar	402.26
Urea + Sugar + K_2SO_4	451.37
Urea + K_2SO_4	444.88
Sem $\pm$	9.57
C. D (0.05)	27.63
I_F (30 DAS)	219.57
I_P (55 DAS)	527.96
I_O (Drought)	495.01
Sem $\pm$	8.56
C. D (0.05)	24.71
I_F Water	159.92
Urea	197.64
Urea + Sugar	212.33
Urea + Sugar + K_2SO_4	273.43
Urea + K_2SO_4	254.52
I_P Water	484.78
Urea	494.60
Urea + Sugar	485.62
Urea + Sugar + K_2SO_4	575.35
Urea + K_2SO_4	599.47
I_O Water	485.62
Urea	494.61
Urea + Sugar	508.82
Urea + Sugar + K_2SO_4	505.34
Urea + K_2SO_4	480.65
Sem $\pm$	19.13
C. D (0.05)	55.25
Control	493.43
Control Vs Rest	414.18
Sem $\pm$	13.97
C. D (0.05)	40.35
CV %	7.91

Fig.15 Effect of nutrient sprays and irrigation on proline content at 55 DAS (ug/g fwt.)



T1:Water

T2:Urea

T3:Urea + Sugar

T4:Urea + Sugar + Potassium Sulphate

T5:Urea + Potassium Sulphate

T6:Irrigation at flowering stage

T7:Irrigation at pegging stage

T8:Drought stress

T9:Control

other sprays given at 20 and 45 DAS. Foliar spray of Urea (0.5%), Urea (0.5%) + Sugar (0.25%) at 45 DAS are on par with the proline content obtained from water spray at 45 DAS but significantly higher than the other sprays given at 20 DAS.

4.5 YIELD AND YIELD COMPONENTS

4.5.1 Number of Plants m^{-2}

Number of plants m^{-2} was same in all the treatment plots (Table 16 and Fig. 16).

4.5.2 Number of pods plant⁻¹

Foliar spray of nutrients followed by irrigation significantly increased the number of pods plant⁻¹ (5.22). Foliar spray of nutrients has no significant effect on the number of pods plant⁻¹ (Table 16 and Fig. 16). Irrigation was found to have significant effect on the number of pods plant⁻¹. Irrigation either at 55 DAS or at 30 DAS produced significantly higher number of pods plant⁻¹ compared to drought treatment. Between two different times of irrigation, irrigation at 30 DAS produced more number of pods plant⁻¹ (6.58). Less number of pods plant⁻¹ was produced with drought conditions (3.31).

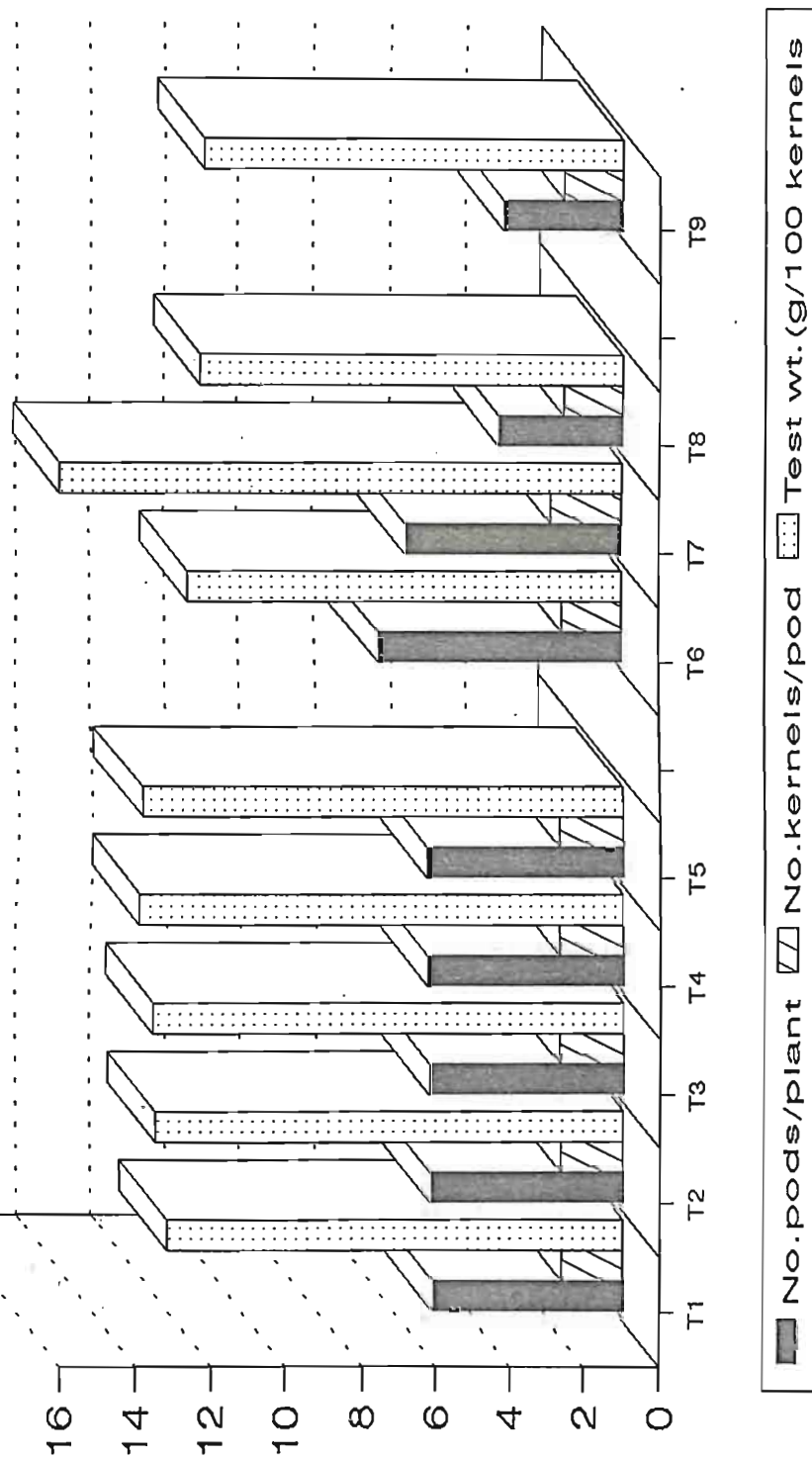
4.5.3 Number of kernels pod⁻¹

Foliar nutrition followed by irrigation significantly increased the number of kernels pod⁻¹ (1.70). Foliar application

Table 16: Effect of nutrient sprays and irrigation on the yield components of groundnut.

Treatments	No. of plants m ⁻²	No. of pods plant ⁻¹	No. of kernels pod ⁻¹	Test weight (g)
Water	29.73	5.14	1.66	12.19
Urea	29.63	5.17	1.69	12.47
Urea + Sugar	29.76	5.24	1.70	12.56
Urea + Sugar + K ₂ SO ₄	29.68	5.28	1.72	12.99
Urea + K ₂ SO ₄	29.61	5.29	1.72	12.90
Sem ±	0.25	0.11	0.01	0.09
C. D (0.05)	NS	NS	0.03	0.27
I _F (30 DAS)	29.94	6.58	1.62	11.61
I _P (55 DAS)	29.90	5.79	1.90	15.02
I _O (Drought)	29.20	3.31	1.58	11.23
Sem ±	0.22	0.10	0.01	0.08
C. D (0.05)	0.64	0.28	0.03	0.24
I _F Water	29.94	6.50	1.58	11.23
Urea	29.90	6.57	1.62	11.47
Urea + Sugar	30.00	6.60	1.62	11.53
Urea + Sugar + K ₂ SO ₄	29.97	6.57	1.65	11.97
Urea + K ₂ SO ₄	29.90	6.67	1.63	11.83
I _P Water	29.97	5.50	1.84	14.10
Urea	29.80	5.73	1.87	14.73
Urea + Sugar	29.97	5.80	1.89	14.87
Urea + Sugar + K ₂ SO ₄	29.97	6.00	1.95	15.80
Urea + K ₂ SO ₄	29.80	5.90	1.94	15.60
I _O Water	29.27	3.43	1.58	11.23
Urea	29.20	3.20	1.59	11.20
Urea + Sugar	29.30	3.33	1.58	11.27
Urea + Sugar + K ₂ SO ₄	29.10	3.27	1.58	11.20
Urea + K ₂ SO ₄	29.13	3.30	1.58	11.27
Sem ±	0.50	0.22	0.02	0.18
C. D (0.05)	NS	NS	NS	0.53
Control	29.17	3.20	1.56	11.17
Control Vs Rest	29.68	5.22	1.70	12.62
Sem ±	0.36	0.16	0.02	0.13
C. D (0.05)	NS	0.46	0.05	0.39
CV %	2.90	7.48	2.35	2.54

Fig.16 Effect of nutrient sprays and irrigation on the yield components of groundnut.



T1: Water
 T2: Urea
 T3: Urea + Sugar
 T4: Urea + Sugar + Potassium Sulphate
 T5: Urea + Potassium Sulphate
 T6: Irrigation at flowering stage
 T7: Irrigation at pegging stage
 T8: Drought stress
 T9: Control

of nutrients significantly increased number of kernels pod^{-1} (Table 16 and Fig. 16). Foliar nutrition of Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) produced more number of kernels pod^{-1} (1.72) and it was on par with Urea (0.5%) + K_2SO_4 (0.25%) spray (1.72). Significantly more number of kernels pod^{-1} was observed in irrigated conditions compared with drought conditions. Irrigation at 55 DAS increased number of kernels pod^{-1} (1.9) when compared with irrigation at 30 DAS (1.62). Growing groundnut with residual moisture conditions resulted in significantly less number of kernels pod^{-1} (1.58).

4.5.4 Test Weight ($\text{g } 100^{-1}$ kernels)

Foliar spray of Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) produced kernels with high test weight (12.99) compared to other treatments and it was on par with Urea (0.5%) + K_2SO_4 (0.25%) spray (12.90). Among different nutrient sprays Urea (0.5%) spray produced seeds with less test weight (12.47) (Table 16 and Fig. 16).

Significantly higher test weight was observed in irrigation at 55 DAS (15.02) compared to irrigation at 30 DAS (11.61). Drought treatment produced significantly lower test weight (11.23).

Significantly higher test weight was recorded with the foliar spray of Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) at 45 DAS followed by irrigation at 55 DAS (15.80) and it was on par with the test weight observed with the foliar spray of Urea (0.5%) + K_2SO_4 (0.25%) and significantly differed from Urea (0.5%) and Urea (0.5%) + Sugar (0.25%) spray at 30 DAS followed by irrigation at 55 DAS. Foliar spray of nutrients except Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) spray (11.97) and Urea (0.5%) + K_2SO_4 (0.25%) (11.83) at 20 DAS followed by irrigation at 30 DAS did not show significant difference in test weight from the foliar spray of nutrients at 80 DAS with residual moisture conditions. Foliar spray of nutrients at 80 DAS under residual moisture conditions did not show any significant increase in the test weight over the plants that were grown with residual moisture conditions with out foliar spray of nutrients (control).

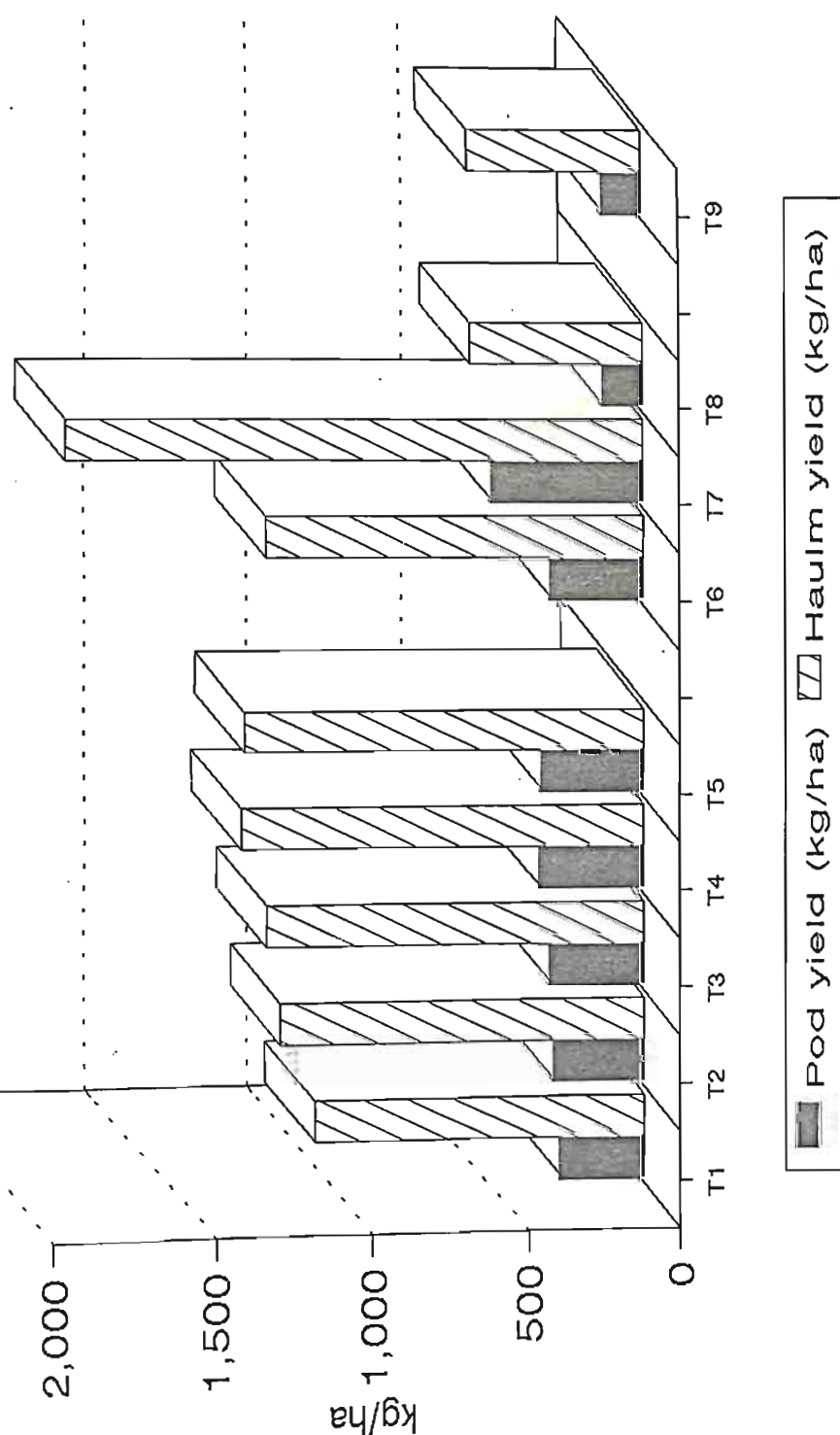
4.5.5 Pod Yield ($kg\ ha^{-1}$)

Foliar nutrition followed by irrigation increased the pod yield (307.43) significantly over unsprayed plots grown with drought conditions (129.09) (control). Foliar spray of nutrients at 80 DAS with residual moisture conditions did not increase the pod yield significantly over unsprayed plots grown with residual moisture conditions (control) (Table 4.17 and Fig. 17).

Table 17: Effect of nutrient sprays and irrigation on pod yield and harvest index of groundnut.

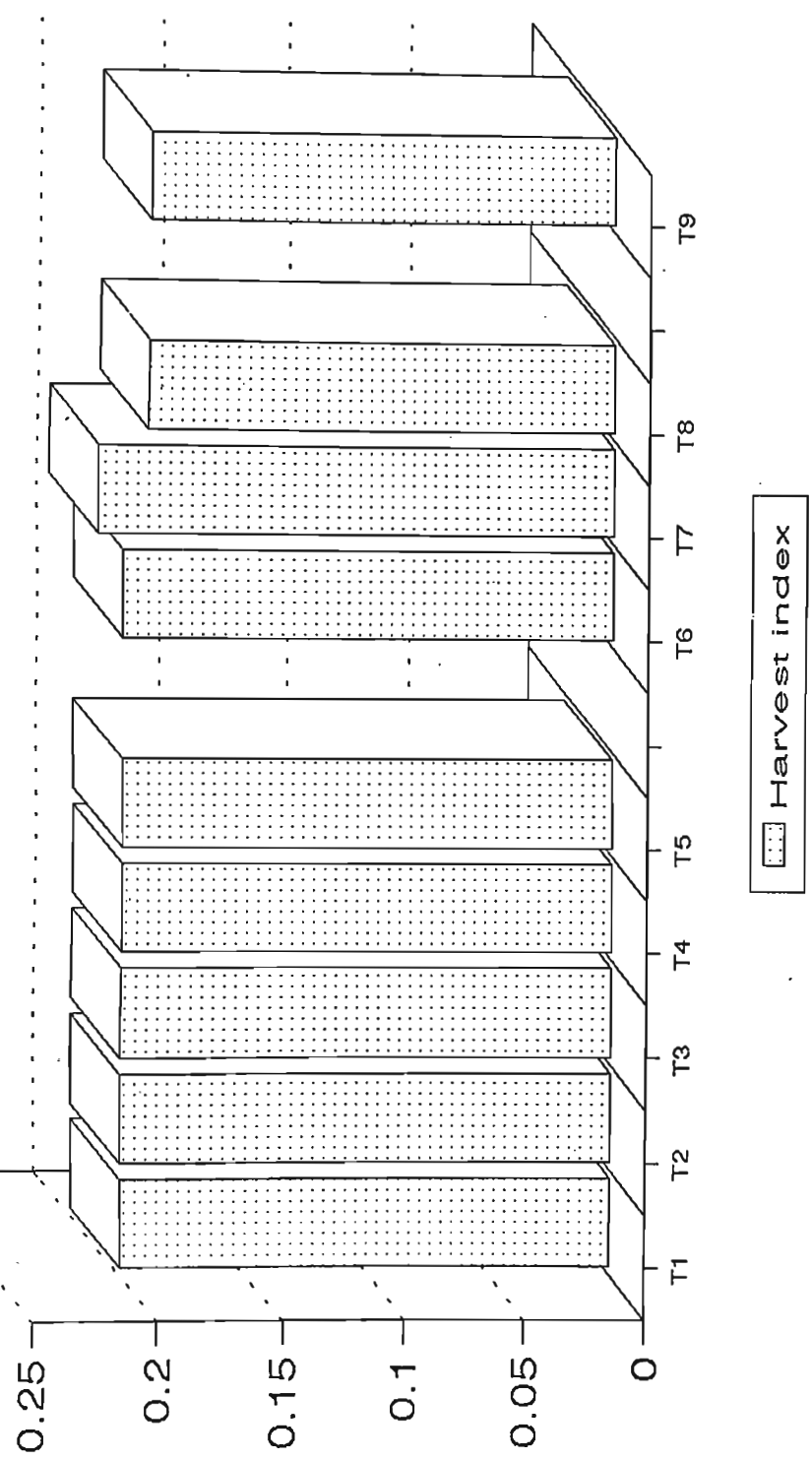
Treatments	Pod yield (kg ha ⁻¹)	Haulm yield (kg ha ⁻¹)	Harvest Index
Water	273.79	1,062.96	0.20
Urea	295.59	1,168.15	0.20
Urea + Sugar	303.32	1,213.33	0.20
Urea + Sugar + K ₂ SO ₄	336.54	1,294.81	0.20
Urea + K ₂ SO ₄	330.69	1,282.96	0.20
Sem ±	6.08	20.69	0.01
C. D (0.05)	17.55	59.74	NS
I _F (30 DAS)	305.28	1,214.44	0.20
I _P (55 DAS)	487.87	1,839.56	0.21
I _O (Drought)	130.80	559.33	0.19
Sem ±	5.43	18.50	0.01
C. D (0.05)	15.69	53.43	0.02
I _F Water	269.10	1,063.33	0.20
Urea	297.27	1,170.00	0.20
Urea + Sugar	302.34	1,242.22	0.20
Urea + Sugar + K ₂ SO ₄	327.06	1,287.78	0.20
Urea + K ₂ SO ₄	330.63	1,308.89	0.20
I _P Water	425.30	1,592.22	0.21
Urea	462.69	1,783.33	0.21
Urea + Sugar	477.11	1,833.33	0.21
Urea + Sugar + K ₂ SO ₄	547.01	2,033.33	0.21
Urea + K ₂ SO ₄	527.24	1,955.56	0.21
I _O Water	126.96	533.33	0.19
Urea	126.82	551.11	0.19
Urea + Sugar	130.50	564.44	0.19
Urea + Sugar + K ₂ SO ₄	135.55	563.33	0.19
Urea + K ₂ SO ₄	134.18	584.44	0.19
Sem ±	12.15	41.37	0.01
C. D (0.05)	35.09	119.48	NS
Control	129.09	565.56	0.19
Control Vs Rest	307.99	1,204.44	0.20
Sem ±	8.87	30.22	0.01
C. D (0.05)	25.63	87.26	NS
CV %	7.09	6.15	10.71

Fig.17 Effect of nutrient sprays and irrigation on the pod yield & haulm yield (kg/ha) of groundnut.



- T1: Water
 T2: Urea
 T3: Urea + Sugar
 T4: Urea + Sugar + Potassium Sulphate
 T5: Urea + Potassium Sulphate
 T6: Irrigation at flowering stage
 T7: Irrigation at pegging stage
 T8: Drought stress
 T9: Control

Fig.18 Effect of nutrient sprays and irrigation on the harvest index of groundnut.



- T1: Water
- T2: Urea
- T3: Urea + Sugar
- T4: Urea + Sugar + Potassium Sulphate
- T5: Urea + Potassium Sulphate
- T6: Irrigation at flowering stage
- T7: Irrigation at pegging stage
- T8: Drought stress
- T9: Control

High pod yield was observed with irrigated conditions when compared with drought conditions. Irrigation at 55 DAS produced highest pod yield (487.87) when compared with the pod yield that was produced by irrigation at 30 DAS (305.28). Growing crop with drought conditions resulted in low pod yield (130.80).

Foliar spray of Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) produced significantly highest pod yield than other nutrient sprays except with Urea (0.5%) + K_2SO_4 (0.25%) spray. The rest of the foliar nutrition treatments i.e., Urea (0.5%) and Urea (0.5%) + Sugar (0.25%) produced pod yield significantly higher than the water spray.

Foliar spray of Urea (0.5%) and Urea (0.5%) + Sugar (0.25%) at 20 DAS followed by irrigation at 30 DAS did not show significant effect on pod yield over water spray. But foliar nutrition of Urea (0.5%) + K_2SO_4 (0.25%) spray at 20 DAS followed by irrigation at 30 DAS significantly produced higher pod yield (330.63) over water spray and it was on par with that of the Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) (327.06). Foliar spray of Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) at 45 DAS followed by irrigation at 55 DAS produced the highest pod yield (547.01) which was on par with the pod yield produced by the foliar spray of Urea (0.5%) + K_2SO_4 (0.25%) (527.24). Foliar

nutrition at 80 DAS with residual moisture conditions did not increase the pod yield significantly over water spray.

4.5.5 Haulm Yield (kg ha^{-1})

Foliar nutrition followed by irrigation increased the yield (1,204.44) significantly over unsprayed plots grown with drought conditions (565.56) (control) (Table 4.17 and Fig. 17).

High haulm yield was observed with irrigated conditions when compared with drought conditions. Irrigation at 55 DAS produced highest yield (1839.56) when compared with the yield produced by irrigation at 30 DAS (1214.44). Lowest haulm yield was produced under drought conditions resulted in low yield (559.33)

Foliar spray of nutrients significantly produced high haulm yield over water spray. Foliar spray of Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) produced significantly high haulm yield than other nutrient sprays except Urea (0.5%) + K_2SO_4 (0.25%) spray. The rest of the foliar nutrition treatments i.e., Urea (0.5%) and Urea (0.5%) + Sugar (0.25%) are also significantly higher than the water spray.

Foliar spray of Urea (0.5%) at 20 DAS followed by irrigation at 30 DAS did not show significant effect on haulm yield over spray. Foliar nutrition of Urea (0.5%) + K_2SO_4 (0.25%) spray

at 20 DAS followed by irrigation at 30 DAS significantly produced higher haulm yield (1,308.89) over water spray and it was on par with that of the Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) (1,287.78) and Urea (0.5%) + Sugar (0.25%). Foliar spray of Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) at 45 DAS followed by irrigation at 55 DAS produced the highest haulm yield (2,033.33) over all other treatments and it was on par with the yield produced by the foliar spray of Urea (0.5%) + K_2SO_4 (0.25%) (1,955.56). Foliar nutrition at 80 under residual moisture conditions did not increase the yield significantly over water spray.

4.5.6 Harvest Index (HI)

Foliar nutrition followed by irrigation has no effect on the harvest index (Table 17 and Fig. 17). There was no significant effect of foliar nutrition on harvest index. Significantly higher harvest index was recorded in irrigated treatments over drought treatment. Irrigation at 55 DAS significantly showed high harvest index (0.21) compared to drought stress (0.19) but was on par with harvest index observed with irrigation at 30 DAS (Table 17 and Fig.17). Harvest index was very less in drought treated plots (0.19).

Discussion & Conclusions

CHAPTER - V

DISCUSSION & CONCLUSIONS

Water is the paramount abiotic factor affecting crop productivity, as it is required for all the biological activities. So, seasonal rainfall deficits create drought situations under which the crop yield is reduced. Droughts are complex situations during which crops may experience various combinations of water, heat and nutrient stress as a result of inadequate water supply. Dry matter accumulation and its partitioning, yield components and yield of groundnut are greatly influenced by the time, duration and occurrence of drought at different phenophases. Drought is also very well known to influence the plant water status, stomatal activities altering leaf temperature. Drought stress is also known to bring about a change in biochemical activities in the direction leading to the accumulation of some amino acids like proline, which is known for osmotic adjustment. Under these situations spraying plants with fertilizers that provide with important elements (N and K which become limiting under drought stress) and that help in maintaining water balance in the leaf tissue may be useful to the plants to some extent in ameliorating the ill effects of drought stress and increasing crop yields. Keeping these aspects in view, an experiment was conducted to study the negative effects of drought stress on growth and yield and the

role of foliar spray in increasing growth and pod yield under drought stress conditions.

5.1 GROWTH CHARACTERS & PARAMETERS

Drought stress decreased the growth characters and parameters like plant height, number of branches plant⁻¹, number of leaves plant⁻¹, leaf area, leaf area index and relative growth rate, but increased the days to 50% flowering. Decrease in plant height with moisture stress was also reported by Ali and Alam (1973) and Tamala Reddy (1983) and Varughese and Irutharaj (1993) in green gram and Subash babu (1977) in groundnut.

In the present study on drought stress it was found that drought stress not only decreased area of individual leaf but also decreased total number of leaves plant⁻¹. Decrease in number of leaves and stem and leaf dry matter with water stress was earlier observed by Ferreria *et al.* (1992) in cotton. Decrease in stem and leaf dry matter accumulation observed in the present study was similar with the findings of earlier workers who reported a decrease in dry matter accumulation under drought stress in groundnut (Garara and Yadav, 1992), in cotton (Jordan, 1970) and in mungbean (Haqqani and Pandey, 1994).

Decrease in leaf area under water stress was also reported by Shahid Umar *et al.* (1993) in sorghum and Naidu

et al. (2001) in greengram. The detrimental effect of moisture stress on dry matter production and leaf area was similar with the findings of Sastry *et al.* (1979), Sabale and Khuspe (1986) in groundnut and Adjei-Twum and Splittstoesser (1976) and Sivakumar and Shaw (1978) in soybean. In the present investigation there was a decrease in LAI due to the decrease in leaf area development. Sensitivity of LAI to water stress was reported by Roller and Pierre (1973). Huck *et al.* (1981) found that leaf area index was drastically reduced under water stress. Golakiya and Patel (1992) also reported a decrease in LAI under moisture stress in groundnut.

The decrease in water potential affects water movement into growing regions and cell elongation rate (Bradford and Hsiao, 1982). Drought decreased leaf elongation rate, appearance and leaf development. Drought affected cell elongation and cell production (Zorica Joranovic, 2001). Recently it has been shown that increasing the p^H of xylem sap is a drought signal that reduces leaf growth through ABA dependent mechanism (Bacon *et al.* 1998). All these factors caused a decrease in plant height, no. of leaves plant⁻¹, stem and leaf dry matter and leaf area.

Irrigation at 30 or 55 DAS brought an increase in all these characters except days to 50% flowering which was

decreased by about 3 days with irrigation at 30 DAS. The greater increase in plant height and number of branches plant⁻¹ was observed when irrigation was given at early stages i.e. at 30 DAS, number of leaves plant⁻¹, stem and leaf dry weight, leaf area and leaf area index were more at harvest with irrigation at 55 DAS which makes us to conclude that water deficit up to 55 DAS did not decrease these growth characters and parameters over water stress upto 30 DAS. Irrigation at 55 DAS helped in retaining more number of leaves plant⁻¹, leaf area, stem and leaf dry weight, leaf area index and relative growth rate was also more at harvest in the plants irrigated at 55 DAS over plants irrigated at 30 DAS. The reason may be that plants irrigated early in the season were prone to drought stress to a greater extent and they became less efficient in producing high pod yields than the plants irrigated late in the season.

Before irrigation either at 30 DAS or 55 DAS the increase in all these growth characters and parameters was in pace with the increase under drought stress. But soon after irrigation there was a tremendous increase in plant height, number of leaves, dry matter production, leaf area, leaf area index and relative growth rate. Decrease in dry matter production and leaf area might be due to decrease in relative growth rate. Jordan (1970) also reported that in cotton relative growth rate

decreased under moisture stress. Sivakumar and Shaw (1978) reported a decrease in relative growth rate in soybean under moisture stress. Increase in dry matter production after release of stress by irrigation was reported by Ramachandrappa *et al.* (1993). Patel *et al.* (1983) reported a sudden increase in leaf area after relieving drought stress either at flowering or pegging.

The decrease in dry matter production could be due to the decrease in photosynthetic rate under water stress (Bala Subramanian, 1990) which was due to highly increased stomatal resistance in groundnut (Pallas *et al.* 1979). Water stress reduced dry matter yield of forages primarily by limiting leaf area development (Ludlow and Ng, 1977 and Ludlow *et al.* 1980).

Leaf fall started early in the plants that were irrigated at 30 DAS because of the reason that irrigation tremendously increased plant height, number of leaves, leaf area and LAI, but these plants faced water stressed condition as they were not irrigated later, as a result leaf fall occurred because the plants failed to maintain leaf water potential above a critical level, leading to the death and abscission of leaves.

Leaf expansion depends mostly on cell expansion. In intact leaves, water stress decreases turgor. As cell expansion is

dependent on turgor, the leaf expansion is decreased under water stress as a result water stress limits the size of individual leaves.

Drought stress was found to increase the days to 50% flowering by about 3 days when compared with irrigation at 30 DAS. Similar finding was reported by Golakiya and Patel (1992) in groundnut where there was an increase in 50% flowering by about 4 – 5 days. Influence of drought stress on the opening of flowers in groundnut (Williams and Rao, 1981) may be the reason for the increase in the days to 50% flowering.

Foliar spray of nutrients increased plant height at 45 DAS and the number of leaves at 75 DAS. The maximum increase in plant height and highest increase in the number of leaves was observed with Urea + Sugar + K_2SO_4 spray followed by Urea + K_2SO_4 spray. There was no response of nutrient sprays on the increase in the number of branches. Foliar nutrition at 20 DAS followed by irrigation at 30 DAS produced maximum plant height. The increase in the plant height with foliar spray of Urea (2%) + KNO_3 (0.5%) + $CaNO_3$ (0.5%) at (50%) flowering stage and 20 days thereafter was reported by Patra *et al.* (1995) in groundnut and with K_2SO_4 at vegetative stage and flower initiation twice on alternate days by Gururaja Rao and Yadav (1997). In the present study there was no effect of foliar nutrition on the number of branches plant⁻¹ however, increase in

the number of branches plant⁻¹ with the foliar spray of DAP (2%) was reported in cowpea by Srinivasan and Rangaswamy (1992) and with K₂SO₄ in groundnut by Gururaja Rao and Yadav (1997). Foliar spray of nutrients increased stem dry weight, leaf dry weight and leaf area. Foliar spray of Urea + Sugar + K₂SO₄ showed highest response on stem dry weight and leaf dry weight, leaf area and leaf area index followed by Urea + K₂SO₄. But at harvest, water spray and urea spray produced similar quantity of leaf dry matter and leaf area.

Foliar spray of nutrients at 45 DAS followed by irrigation at 55 DAS produced maximum stem dry weight followed by irrigation at 30 DAS. Among all the nutrient sprays maximum stem dry weight was produced by the foliar spray of Urea + Sugar + K₂SO₄ followed by Urea + K₂SO₄. Foliar spray of nutrients at 45 DAS followed by irrigation at 55 DAS produced maximum leaf area and leaf dry weight. The highest positive effect on the leaf dry matter production was observed with Urea + Sugar + K₂SO₄ followed by Urea + K₂SO₄. Foliar nutrition at 20 DAS followed by irrigation also increased leaf area and leaf dry weight. The highest increase in leaf dry matter was observed with the Urea + Sugar + K₂SO₄ spray followed by Urea + K₂SO₄ spray. But at harvest they are all on a par for leaf dry matter production. Increase in dry matter production was also reported by Sarkar

et al. (1999) with the foliar spray of KNO_3 (0.5%) or KNO_3 (0.25%) + CaNO_3 (0.203%) and Patil *et al.* (1984) with the foliar spray of Ferrous Sulphate (0.5%) + Urea (2%) in groundnut. Increase in dry matter production with foliar spray was also reported in other crops like Das and Sarkar (1981) in rice and wheat with KNO_3 spray.

Increase in leaf area with the foliar sprays might be due to the positive effect of nutrients like N and K present in the spray solution. Sarkar *et al.* (1999) reported an increase in leaf area index with the foliar spray of KNO_3 (0.5%) or KNO_3 (0.25%) + CaNO_3 (0.203%) and Patra (1995) with Urea (2%) + KNO_3 (0.5%) + CaNO_3 (0.5%).

Relative growth rate significantly decreased with the foliar spray of nutrition. The highest decrease in relative growth rate with the foliar spray of Urea + Sugar + K_2SO_4 followed by Urea + K_2SO_4 . Relative growth rate was more with the foliar spray of water at 75 – 90 DAS.

Relative growth rate was more between 65 – 75 DAS and at 75 – 90 DAS with the foliar spray of nutrients at 45 DAS followed by irrigation at 55 DAS. The relative growth rate was increased with Urea + Sugar + K_2SO_4 and Urea + K_2SO_4 with the highest value recorded with Urea + Sugar + K_2SO_4 spray between

60-75 DAS. Between 75 – 90 DAS relative growth rate was maximum with foliar spray of water followed by Urea + Sugar spray. Foliar spray of nutrients increased the relative growth rate initially, but decreased to a lowest at later stages with the foliar spray Urea + Sugar + K_2SO_4 and Urea + K_2SO_4 . This may be due to the efficient translocation of nutrients to pods initially and decrease in the rate of growth later due to more stress. In case of foliar nutrition at 20 DAS followed by irrigation at 30 DAS relative growth rate was maximum with water spray followed by Urea spray between 60 – 75 DAS and 75 – 90 DAS.

There was no significant difference in specific leaf weight with respect to the drought stressed and irrigated plants. However, a significant increase in specific leaf weight was recorded with drought treatment due to production of less leaf area with more thicked leaves (Pandey *et al.* 1984). Foliar spray of nutrients also did not show significant change in specific leaf weight, however, specific leaf weight was more in plants sprayed with Urea + Sugar + K_2SO_4 and Urea + K_2SO_4 . An increase in specific leaf weight was reported with foliar spray of K_2SO_4 by Gururaja Rao and Yadav (1997).

5.3 BIOCHEMICAL PARAMETER

Proline is one of the most compatible osmolytes in water stressed plants. Drought stress increased the proline

content of the leaf over irrigated treatment. The accumulation of proline in dehydrated plants is caused by the activation of the biosynthesis of proline and by the deactivation of degradation of proline (Yoshida *et al.*, 1997). Similar findings of increase in proline content was reported by Mehri *et al.* (1997) in groundnut and by Sharma *et al.* (1990) and Shahid Umar *et al.* (1991) in chickpea and by Naidu *et al.* (2001) in greengram.

Irrigation at 30 DAS did not increase proline content at 55 DAS. Vinod Goyal *et al.* (2001) reported the decrease in leaf proline content after irrigation in hybrid pearl millet.

Foliar spray of Urea + Sugar + K_2SO_4 and Urea + K_2SO_4 were only found to increase the leaf proline content. The increase in proline level with these sprays might be the effect of potassium element present in these nutrient sprays. Foliar spray of nutrients at 20 DAS followed by irrigation at 30 DAS decreased the leaf proline content over control however, foliar nutrition of Urea + Sugar + K_2SO_4 and Urea + K_2SO_4 at 20 DAS increased the proline level over water spray at 20 DAS followed by irrigation at 30 DAS the reason may be that irrigation increased the leaf area very much in the plants sprayed with these nutrients which made these plants susceptible to drought stress earlier than the plants sprayed with Urea and Urea + Sugar or the other reason may be that potassium might have increase the leaf proline content.

Foliar nutrition of Urea + Sugar + K_2SO_4 and Urea + K_2SO_4 at 45 DAS were found to increase the proline content at 55 DAS. The similar effect of increase in proline content with potassium nutrition was earlier reported by Krishna Sastry (1985) and Shahid Umar *et al.* (1991).

5.2 PHYSIOLOGICAL PARAMETERS

Relative water content is a measure of water status of the plant. Drought stress gradually decreased the relative water content. Decrease in the relative water content with drought stress had been reported earlier by Shahid Umar *et al.* (1991) in groundnut and by Ravichandram and Mungse (1997) in wheat. The decrease in relative water content of leaf was progressive with the decrease in soil moisture status during crop growth. At harvest high relative water content was observed in the leaf of the plant that was irrigated at 55 DAS. Relative water content increased only with the foliar spray of Urea + Sugar + K_2SO_4 and Urea + K_2SO_4 spray. Increase in relative water content with these two foliar sprays might be due to the effect of K^+ in retaining moisture in leaves during drought period as reported by Larsen (1981) in conifers. Increase in the relative water content with potassium application coupled with reduction in water loss was reported in sorghum by Shahid Umar *et al.* (1993). Foliar spray of Urea + Sugar + K_2SO_4 and Urea + K_2SO_4 increased

relative water content at 45 DAS when spraying at 20 DAS was followed with irrigation at 30 DAS, but later the differences became non-significant.

Leaf stomatal resistance and leaf temperature was maximum under drought stress when compared with irrigation at 30 or 55 DAS. Stomatal resistance gradually increased from sowing to harvest but recorded less values during the days followed after irrigation. The results were in agreement with the findings of Pallas *et al.* (1979) and Mohan Singh *et al.* (1993). Decrease in stomatal conductance under drought stress was reported by Bala Subramanian and Maheswari (1990) and Bala Subramanian *et al.* (1993).

Increase in canopy temperature under drought stress was reported by Pandey *et al.* (1984) Bala Subramanian *et al.* (1993) and Ravichandram and Mungse (1997) in groundnut and by Tiwari *et al.* (1998) in rice. Foliar spray of Urea + Sugar + K_2SO_4 and Urea + K_2SO_4 significantly increased the stomatal resistance and canopy temperature over water spray. Stomatal resistance might have been increased with the spray of K_2SO_4 . The K^+ present in solution influenced the stomatal closure and increased stomatal resistance thereby decreasing evaporative cooling and increasing leaf temperature. Similarly increase in

stomatal resistance under water stress by K^+ application was reported by Shahid Umar *et al.* (1991).

Foliar spray of Urea + Sugar + K_2SO_4 and Urea + K_2SO_4 at 20 DAS followed by irrigation at 30 DAS or foliar spray of nutrients at 45 DAS followed by irrigation at 55 DAS increased stomatal resistance over water spray at 45 and 60 DAS. At 45 DAS leaf temperature was highest with the foliar spray of Urea + Sugar + K_2SO_4 and Urea + K_2SO_4 at 20 DAS followed by irrigation at 30 DAS. The differences were non-significant at later stages.

5.4 YIELD AND YIELD COMPONENTS

Number of pods per plant, number of kernels pod^{-1} , test weight of 100 kernels, haulm yield and pod yields were significantly reduced under drought stress. Decrease in the number of kernels pod^{-1} and test weight under moisture stress was also reported by Venkateswara Rao *et al.* (1986) and decrease in the number of pods and test weight was observed in groundnut by Pandey *et al.* (1984). Patel and Golakiya (1991) also recorded great reduction in total and developed pods and reduced weight of seed due to moisture stress. The decrease in the number of pods might be because of the low peg penetration due to increased soil resistance to peg penetration caused by prolonged drought (Sarma and Siva Kumar, 1991).

Irrigation at 30 DAS produced more number of pods than irrigation at 55 DAS, but recorded lower test weight than irrigation at 55 DAS. Because of the increase in number of pods the dry matter translocated to the pods was not able to fill the pods completely. Increase in the number of pods might be due to the increased number of flowers and peg penetration with irrigation at flowering. Decrease in number of kernels pod⁻¹ under moisture stress was reported by Dhopte *et al.* (1992) in groundnut and Surya Kumari *et al.* (2000) in blackgram. Dhopte *et al.* (1992) also reported reduction in pod yield with drought.

Pod yield was less in irrigation at 30 DAS treatment compared with irrigation at 55 DAS due to decreased test weight and number of kernels pod⁻¹. The reason may be that water deficit observed at later stages in irrigation at 30 DAS resulted in less number of kernels pod⁻¹. Highest reduction in groundnut yields due to moisture stress during pod filling was observed by Patel and Golakiya (1991), Stirling and Black (1991) and Meisner and Karnok (1992). Significant reduction in pod yield due to moisture stress at 50-70 DAS and 70-90 DAS was reported by Sridhara *et al.* (1996). Less pod yield than irrigation at 55 DAS was observed under complete drought stress or irrigation at 30 DAS because the pod development stage alone or in combination with any other stages was sensitive to pod yield according to

Garara and Yadav (1992). Also the more increase in yield with irrigation at 55 DAS was due to the fact that moisture stress at the early stages reduced the sensitivity of groundnut to subsequent drought resulting in increased yield at later stages due to better distribution of dry matter into reproductive components (Nageswara Rao *et al.*, 1985).

Decrease in haulm yield was observed with the drought stress. Pandey *et al.* (1984) also recorded decrease in total dry matter yield under drought conditions.

Harvest index was significantly decreased in drought stress treatment over irrigation at 55 DAS. Similar decrease in harvest index under moisture stress in grains legumes was reported by Pandey *et al.* (1984).

Foliar spray of Urea, Urea + Sugar, Urea + Sugar + K_2SO_4 , Urea + K_2SO_4 did not increase the number of pods plant⁻¹ and harvest index but increased number of kernels pod⁻¹, test weight, haulm and pod yield. The highest increase in number of kernels pod⁻¹, test weight, haulm and pod yield was observed with Urea + K_2SO_4 + Sugar followed by Urea + K_2SO_4 .

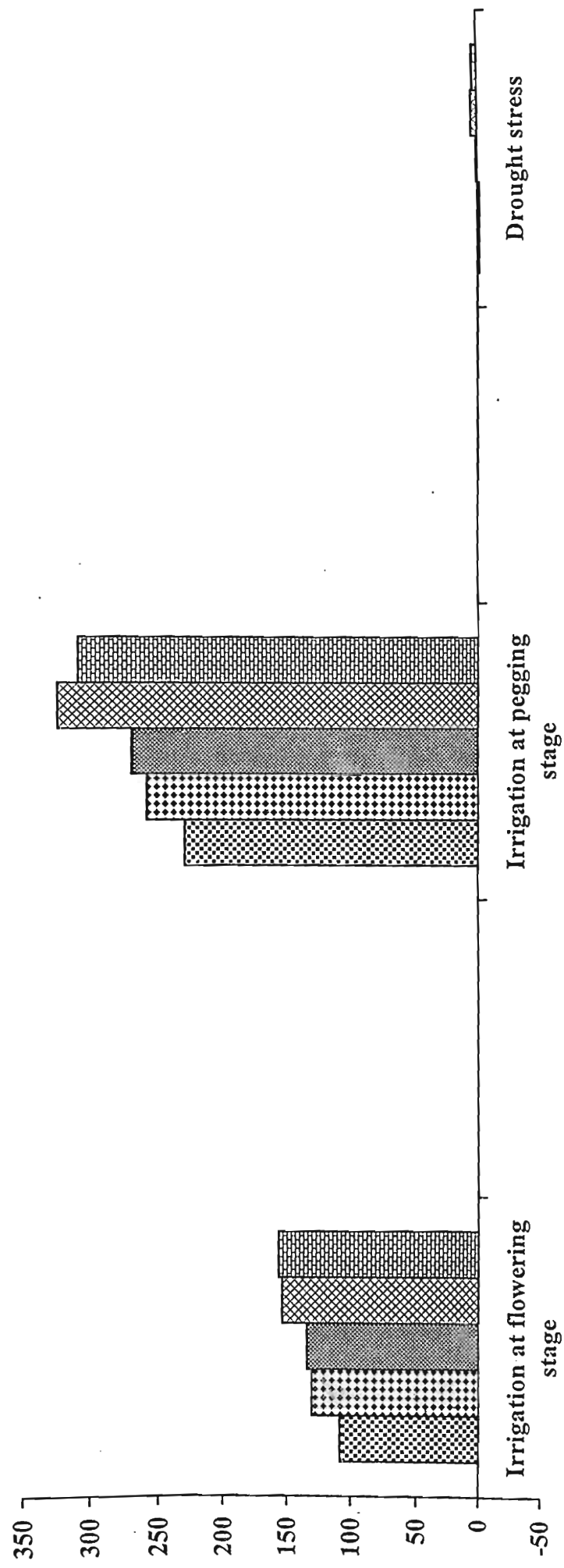
Foliar spray of Urea + K_2SO_4 + Sugar and Urea + K_2SO_4 at 20 DAS followed by irrigation at 30 DAS only increased test weight, where as foliar spary of all the nutrients at 45 DAS

followed by irrigation at 55 DAS increased the test weight. Highest test weight was recorded under this treatment with the foliar spray of Urea + Sugar + K_2SO_4 and Urea + K_2SO_4 . At harvest the highest haulm and pod yield was recorded with the foliar nutrition of Urea, Urea + Sugar, Urea + Sugar + K_2SO_4 and Urea + K_2SO_4 at 45 DAS followed by irrigation at 55 DAS with the highest haulm and pod yield produced from Urea + Sugar + K_2SO_4 spray followed by Urea + K_2SO_4 spray.

Nutrient sprays of Urea, Urea + Sugar, Urea + Sugar + K_2SO_4 and Urea + K_2SO_4 at 20 DAS followed by irrigation at 30 DAS increased pod yield to the extent of 108.5, 130.3, 134.2, 153.4, 156.1 respectively over control (unsprayed and unirrigated) and Nutrient sprays of Urea, Urea + Sugar, Urea + Sugar + K_2SO_4 and Urea + K_2SO_4 at 45 DAS followed by irrigation at 55 DAS increased pod yield to the extent of 229.5, 258.4, 269.6, 323.7, 308.4 respectively over control. There was no significant effect of nutrient sprays at 80 DAS on the pod yield over control.

Foliar spray of Urea did not increase the haulm yield over water spray. But all other nutrient sprays are significantly higher in haulm yield over water spray and are on par with each other. Urea + Sugar + K_2SO_4 and Urea + K_2SO_4 spray only produced highest pod yield over water spray at 20 DAS followed

Fig. 19 Percent increase in pod yield over control (no irrigation and no foliar spray) with the nutrient sprays under different irrigation treatments and drought stress.



Water Urea Urea + Sugar Urea + Sugar + Potassium Sulphate Urea + Potassium Sulphate

by irrigation at 30 DAS. However, increase in number of pods plant⁻¹, seeds pod⁻¹ was reported by Srinivasan and Ramaswamy (1992) with DAP (2%) spray in rainfed cowpea by Sarkar *et al.* (1999) with KNO₃ (0.5%) or KNO₃ (0.25%) + CaNO₃ (0.203%) in groundnut reported increase in the number of pods plant⁻¹, kernels pod⁻¹ test weight and pod yield. Similarly increase in the number of pods plant⁻¹ and number of seeds pod⁻¹ was reported by Bharud *et al.* (1986) with the foliar spray of 2% Urea.

Increase in pod yields was also reported with the spray of Urea (1.5%) + DAP (0.5%) at 20, 40 and 55 DAS by Bhalaerao *et al.* (1994) in groundnut. Foliar application of KNO₃ solution in rice and wheat increased straw yield (DAS and Sarkar, 1981). Patil *et al.* (1984) reported an increase in dry matter production and its accumulation in pods at harvest with Ferrous Sulphate (0.5%) + Urea (2%).

CONCLUSIONS

The following conclusions can be drawn from the investigation:

1. Application of foliar nutrient sprays was found to significantly increase the stem and leaf dry matter accumulation and yield of groundnut. The increase in pod yield due to sprays of Urea (0.5%), Urea (0.5%) + Sugar (0.25%), Urea (0.5%) + Sugar (0.25%) + K₂SO₄ (0.25%) and Urea (0.5%) + K₂SO₄ (0.25%)

was to the extent of 7.96, 10.78, 18.6, 17.2% respectively over control.

2. Drought stress (I_0) significantly decreased the plant height, number of branches plant⁻¹, number of leaves plant⁻¹, stem and leaf dry matter accumulation, leaf area and relative water content, but increased days to 50% flowering by about 3 days, proline content, stomatal resistance and leaf temperature. Relative growth rate also decreased under drought stress finally leading to decreased pod yield with its effect from yield components.
3. Irrigation at 55 DAS was found to have beneficial effect on the pod yield over irrigation at 30 DAS. So we can conclude that when there is only a chance of providing one irrigation to the groundnut crop then scheduling it in the later part of the season would be useful rather than giving it in the early stages as irrigation at 55 DAS would be close to the pod development and seed formation stage.
4. Irrigation and nutrients sprays interaction suggested that foliar nutrition at 45 DAS followed by irrigation at 55 DAS and foliar nutrition at 45 DAS followed by irrigation at 55 DAS recorded high pod yield when compared to foliar nutrition at 20 DAS followed by irrigation at 30 DAS or foliar nutrition at 80 DAS under drought stress. There was no use of spraying foliar nutrients at 80 DAS under drought conditions. Plants sprayed

with foliar nutrients at 80 DAS might not be able to utilize the opportunity due to lack of water for proper biochemical activities. This enhancement in yield was due to increased stem and leaf dry matter accumulation and maintenance of relative water content at higher levels than the other treatments during pod filling phase and pod maturation stage.

5. Among the four nutrient sprays, Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) performed well in alleviating drought stress followed by Urea (0.5%) + K_2SO_4 (0.25%) and Urea (0.5%) + Sugar (0.25%) and Urea (0.5%). The highest increase in yield with Urea + K_2SO_4 + Sugar followed by Urea + K_2SO_4 was due to the fact that they supplied important nutrients (N, P and S) and resulted in increased stem and leaf dry matter accumulation and also increased relative water content of the leaves, stomatal resistance and proline content and finally increased yield components of groundnut.

Summary

CHAPTER - VI

SUMMARY

A field experiment was carried out in sandy loam soils of Agricultural College Farm, Bapatla during the *rabi* of 2000 – 2001 to study the effect of foliar nutrition of groundnut under drought stress. The investigation was carried out by taking different times of irrigation/no irrigation as one factor (irrigation at 30 DAS, irrigation at 55 DAS and no irrigation as drought treatment) and different nutrient sprays as another factor (Water spray, Urea (0.5%), Urea (0.5%) + Sugar (0.25%), Urea (0.5%) + Sugar (0.25%) + K₂SO₄ (0.25%), Urea (0.5%) + K₂SO₄ (0.5%). These nutrient sprays were given at 10 days before irrigation in irrigated treatments and at 80 DAS in drought treatment. One control plot was taken for all the treatments in which sprayings and irrigation were not given.

Non destructive and destructive growth analysis was done for every 15 days interval after sowing for plant height, number of leaves plant⁻¹, number of branches plant⁻¹, stem and leaf dry matter accumulation and leaf area. Physiological parameters like leaf relative water content was recorded and stomatal resistance and canopy temperature were also measured at 15 days interval after sowing. Proline content of the leaf was estimated at 55 DAS.

Drought stress decreased all growth characters like plant height, number of leaves plant⁻¹, number of branches plant⁻¹, stem and leaf dry matter accumulation and leaf area finally affecting the yield components like number of pods plant⁻¹, test weight and number of kernels pod⁻¹ significantly decreasing the pod yield when compared with irrigated treatment.

Irrigation at 55 DAS was found to be superior over irrigation at 30 DAS due to the maintenance of high leaf relative water content at pod development and pod maturation stage and better partitioning of photosynthates to the pods.

Overall growth characters, yield components and yield increased with nutrient sprays in irrigated treatment. But in irrigated treatment foliar nutrition did not show any increase either in growth characters or yield components.

Among different nutrient sprays, Urea + Sugar + K₂SO₄ and Urea + K₂SO₄ recorded high leaf relative water content over water spray. Canopy temperature and stomatal resistance also increased with Urea + Sugar + K₂SO₄ and Urea + K₂SO₄ spray.

Foliar nutrition of Urea (0.5%), Urea (0.5%) + Sugar (0.25%), Urea (0.5%) + Sugar (0.25%) + K₂SO₄ (0.25%), Urea

(0.5%) + K_2SO_4 (0.25%) recorded 7.96, 10.78, 18.6, 17.2 per cent increase in pod yield respectively over water spray. Out of all the nutrient sprays highest increase in yield over water spray was recorded with Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%) followed by Urea (0.5%) + K_2SO_4 (0.25%).

Foliar nutrition and irrigation interaction suggested that the crop was benefited by the foliar spray of nutrients at 45 DAS followed by irrigation at 55 DAS as it increased the pod yield when compared with foliar nutrition at 20 DAS followed by irrigation at 30 DAS. This enhancement in pod yield was due to maintenance of higher leaf relative water content and better filling of pods due to increased dry matter production. The increase in yield with the foliar nutrition of Urea (0.5%), Urea (0.5%) + Sugar (0.25%), Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%), Urea (0.5%) + K_2SO_4 (0.5%) at 45 DAS followed by irrigation at 55 DAS was to the extent of 8.79, 12.18, 28.6, 19.3 per cent respectively, whereas in case of foliar nutrition of Urea (0.5%), Urea (0.5%) + Sugar (0.25%), Urea (0.5%) + Sugar (0.25%) + K_2SO_4 (0.25%), Urea (0.5%) + K_2SO_4 (0.5%) at 20 DAS followed by irrigation at 30 DAS the increase in yield was to the extent of 10.5, 12.4, 21.5, 22.9 per cent respectively over water spray.

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