RESPONSE OF COTTON *cv.* ABADHITA (*Gossypium hirsutum* L.) TO SOIL AND FOLIAR APPLICATION OF MICRONUTRIENTS UNDER RAINFED CONDITIONS.

R. BASAVARAJAPPA

DIVISION OF AGRONOMY
UNIVERSITY OF AGRICULTURAL SCIENCES, DHARWAD-5

NOVEMBER, 1992

RESPONSE OF COTTON cv. ABADHITA (*Gossypium hirsutum L.*) TO SOIL AND FOLIAR APPLICATION OF MICRONUTRIENTS UNDER RAINFED CONDITIONS

Thesis submitted to the
University of Agricultural Sciences, Dharwad,
in partial fulfilment of the requirements for the
Degree of

MASTER OF SCIENCE (AGRICULTURE)
in
AGRONOMY

By

R. BASAVARAJAPPA

DIVISION OF AGRONOMY
UNIVERSITY OF AGRICULTURAL SCIENCES, DHARWAD

NOVEMBER, 1992

DEPARTMENT OF AGRONOMY

UNIVERSITY OF AGRICULTURAL SCIENCES, DHARWAD

CERTIFICATE

This is to certify that the thesis entitled **"RESPONSE OF COTTON Cv. ABADHITA (*Gossypium hirsutum* L.) TO SOIL AND FOLIAR APPLICATION OF MICRONUTRIENTS UNDER RAINFED CONDITIONS"** submitted by **Mr. R.BASAVARAJAPPA**, for the degree of **MASTER OF SCIENCE (AGRICULTURE) IN AGRONOMY**, of the University of Agricultural Sciences, Dharwad, is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles.

Dharwad

November, 1992

(V.R. KORADDI)

AGRONOMIST AND
SENIOR SCIENTIST (COTTON)
AICCIP. A.R.S. DHARWAD-7.

Approved by:

Chairman : (V.R.KORADDI)

Members : 1. (A.D.JANAWADE)

2. (B.S.JANAGOUDAR)

3. (V.S.DODAMANI)

4. (P.W. BASARKAR)

Affectionately Dedicated to
My Beloved Parents

Shri. Dasikatte Rangappa
Smt. Gowramma
and
Brothers & Sisters

ACKNOWLEDGEMENT

Behind each scientific achievement, are the endeavours of many persons and this fact is most often than not over-looked in the study of science. I, for one, feel that the human element is relegated from it's control position in scientific studies. At this gratifying moment of completion of my research project, I feel obliged to record my gratitude to those who helped me.

My enthusiasm was the rock rolling down the mountain which the sisyphus, like Sarvashri. V.R. Koradi, the Chairman of my advisory committee, Agronomist and Senior Scientist (cotton), A.R.S. Dharwad farm-7, struggled to raise. He guided me on throughout this study. His encouragement, inspiring guidance, valuable suggestions, fruitful criticisms were always a source of inspiration to me.

I record with sincerity my profound sense of grati-tude to Dr. M.N. Sheelavanthar, Chief Scientist (WM), A.R.S. Belavatagi, Dr. G.S. Dasog, Associate Professor, A.R.S. Bheemarayanagudi, Dr. B.S. Janagoudar, Assistant Cotton Breeder, A.R.S. Dharwad Farm, Dharwad-7 and Dr. P.W. Basarkar, Assistant Professor (Basic Chemistry), U. .S. Dharwad-5 who have served as Members of my Advisory Committee, for their valuable guidance, constructive criticisms and critical evaluation of the manuscript.

My diction is too poor to translate the gratitude and heart-felt respects to my beloved parents, brother-in-laws Sri. Thippanna and Sri. Nehru, brothers - Sri. Rudrappa, Thippeswamy and Sisters- Smt. Gangamma and Chandramma, for their love and affection which laid the foundation of my life.

Thanks to Dr. B.R. Hegde, Chief Scientist (Drylands) and Dr. G.N. Gajanana, Soil Physicist (Dryland Agriculture Project), U.A.S., Bangalore-24 for analysing the initial soil samples for available micronutrients.

Thanks to Sri. E.S. Abraham, Cotton Technologist, CIRCOT Unit, B.O., ARS Dharwad Farm and his staff for analysing fibre properties. Thanks to Sri. K.S. Panchabhavi, Entomologist (cotton) for his cooperation during the tenure of part-time period.

Life is not work all the time, one necessarily has to have diversion once in a while to be able to return his work with renewed enthusiasm and vigour and this is where my friends - Gangadhariah, Sub_Registrar, Jevargi,Gulbarga; Shivanna, H., Asst.Professor, Forestry College, Sirsi; M.R. Krishnappa, Asst. Cotton Breeder, ARS Arabhavi; K.S. Kamath, A.K. Guggari and K.N. Kattimani, Research Assistants; M. Hanumanthappa and S. T. Yanjerappa, Research Associates; and Dr.Krishnamurthy, I/c Computer Centre, UAS, Dharwad, played an excellent role. My heartful thanks are due to all of them.

I sincerely express my indebtedness to U.A.S., Dharwad-5 for providing part-time facility. I am also grateful to the authorities of AICCIP and the UAS,Dharwad for favour of finance for conducting experiment and for kind permission to publish the thesis.

My thanks are also due to all of my staff members and friends who have helped me directly or indirectly during the tenure of my study.

Lastly I thank 'AP' for neat typing of the manuscript in a short time.

Place: Dharwad

Date : 30 - 11 - 1992

(R. BASAVARAJAPPA)

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CHAPTER - I

INTRODUCTION

I. INTRODUCTION

Cotton (Gossypium Sp.) is an importat commercial crop in the world. Being a prime supplier of raw material for textile industry, it plays an important role in the Indian economy. Among the cotton growing countries in the world, India occupies the first position in respect of area. Presently the area under cotton in India is 7.6 million hectares, out of which only 2.3 million hectares (30%) is grown with assured irrigation. Remaining 5.3 million hectares (70%) is entirely dependent on erratic and uncertain rainfall varying from 400 mm to 800 mm received hardly for a period of 80 to 100 days (Bonde, 1992). As regards production of cotton, India occupies the fourth position after China, USSR and USA with an annual production of 12 million bales of lint (Basu, 1992).

The average yield in India is only 280 kg lint per hectare as compared to the yield levels of 613, 963 and 1060 kg lint per hectare of USSR, USA and Egypt, respectively (Basu, 1992). The low yield levels necessitate improvement of genetic, agronomic and physiological aspects involved in cotton production, in addition to management of pest and disease complex inspite of the limitations set by climatic factors.

In Karnataka, the area and production during 1990-91 was 5.67 lakh hectares and 6.92 lakh bales of lint, respectively, with an average yield of 204 kg lint per hectare (Anon., 1992).

The northern dry zone of Karnataka, comprising 35 taluks from the entire districts of Bijapur and Bellary, and parts of Belgaum, Dharwad, Chitradurga and Raichur districts is the major cotton growing area. This zone alone contributes 95 per cent of area and 90 per cent of cotton production in the State. Soil and climatic conditions are quite suitable for the cultivation of cotton in this zone particularly under irrigation. With the advent of high yielding varieties and hybrids during the last two decades, intensive cultivation is being followed to exploit the full potential of these varieties/hybrids. This necessitates balanced application of nutrients including micronutrients.

Under the intensive cropping system, proper supply of all essential nutrients including micronutrients to crops assumes greater importance as the native soil nutrients are depleted continuously. This calls for the use of proper blend of all essential nutrients through chemical fertilisers, manures, soil amendments, micronutrient fertilisers, crop residues, biofertilizers etc., to maintain soil fertility and raise the yield levels manifold.

zinc, copper, manganese, iron, boron, molybdenum and chlorine are required by the plants in very small amounts. Nevertheless from nutritional point of view, they are indispensable like any other essential macronutrients.

Zinc is essential for protein and auxin production. Iron helps in photosynthesis, reduction of nitrate, sulphate and assimilation of nitrogen. Manganese is necessary for photosynthesis, CO_2 assimilation and nitrogen metabolism. Copper is a constituent of cytochrome oxidase and many other enzymes. Boron is essential for proper development and differentiation of tissues. Molybdenum is essential for 'N' assimilation and 'N' fixation. Chlorine stimulates activities of some enzymes, influences carbohydrate metabolism and water holding capacity of plant tissues (Anon., 1986).

In order to deal with the emerging problems of micro-nutrient deficiencies, the Indian Council of Agricultural Research initiated an All India Coordinated Research Scheme on micronutrients in soils and plants in 1967.

Among the micronutrients, Zn deficiency is the most predominant and wide-spread. The soils which are coarse and texture, high in pH ($>$8.5), high in $CaCO_3$ ($>$0.5%) and low in orgaic matter($<$0.4% organic carbon) are the ones to show Zn deficiency (Takkar et al., 1989).

Not much work has been done on the response of cotton to soil and foliar application of micronutrients in the country in general and in Karnataka in particular. In recent years, scattered instances of response of cotton to micronutrients have been reported (Malewar, 1981 and Sharma et al., 1988). Hence, in order to see whether yield of cotton can be increased by the application of micronutrients either through soil or through foliar application to rainfed cotton, a study was undertaken at the Agricultural Research Station, Dharwad Farm, Dharwad (Karnataka) during the year 1991-92 with the following objectives :

1. To study the effect of Cu, Zn, Mn, Fe and B applied individually and in combination through soil or foliar application on the growth and growth parameters.
2. To find out the effect of micronutrients on the yield and yield parameters of cotton.
3. To study the effect of micronutrients on fibre properties of cotton.
4. To compare the relative efficacy of soil and foliar application of micronutrients on cotton.
5. To study the uptake of N, P_2O_5 and K_2O by the application of micronutrients.

CHAPTER - II

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Nutrient deficiences in Indian soils and crops are on the increase. In the intensively cultivated areas of the country, the deficiencies of micronutrients have been emerging and posing problems to realisation of potential yields of crop varieties, particularly with the advent of high yielding varieties and hybrids and adoption of intensive crop production technologies.

The consumption of macro nutrients increased by eight fold from 1.1 m.tonnes in 1966-67 to 8.74 m.tonnes in 1986-87. Concurrently increase in the consumption of micro-nutrients especially Zn, Mn and Fe has taken place (Takkar, et al., 1989). This has necessitated to demonstration of micronutrient defieciencies, so that these can be included in the fertiliser schedule for realising the highest yields of cotton crop.

2.1 Status of micronutrients in soils

2.1.1 Copper:

Mann et al., (1972) observed that the available Cu content of Punjab soils varies from 0.08 to 2.6 ppm with a mean value of 0.75 ppm.

Lindsay and Narvell (1978) found 0.2 ppm of Cu content as tentative critical level in Colorado soils of neutral to calcarious nature.

Chakraborthy *et al*. (1979) observed that the available copper content of Assam soils varied from 0.187 to 2.7 ppm. They further reported that soils rich in organic matter exhibited lower amount of available copper.

Singh and Singh (1981) noticed that the total and available copper content of Rajasthan soils vary from 17.2 to 67.8 and 0.23 to 0.84 ppm, respectively.

Joshi *et al*. (1982) reported that the DTPA extractable copper varied from 0.28 to 1.25 ppm with an average of 0.66 ppm.

2.1.2 Manganese:

Mann *et al*. (1972) reported that the available manganese content varied from 1.8 to 38 ppm with an average of 10.54 ppm in Punjab soils.

Rawat and Mathapal (1981) studied the available Mn content of some hill soils of Uttar Pradesh which ranged from 3.6 to 26 ppm with a mean value of 14.5 ppm.

Jha *et al*. (1964) reported that the available Mn in Maharashtra soils varied from 2.09 to 5.62 ppm, but the variation did not follow the physiography of the tract.

According to Murthy and Vishwanath (1987) vertisols of Karnataka were found to have higher amounts of DTPA extractable Mn in the range of 6 - 25 ppm.

2.1.3 Iron:

Iron is most common of the metallic elements in the earth's crust. It's total content in the soils, however ranges from a very low value of 0.02% to 10 per cent.

Viets and Lindsay (1973) reported that soils containing 2.5 ppm of DTPA extractable iron as deficient, 2.5 to 4.5 ppm as marginal and more than 4.5 ppm as adequate.

Kanwar and Randhawa (1974) reviewed the studies on iron content of Indian soils and stated that total iron content varied from 0.4 to 27.3 ppm and the available iron content varied from traces to 98 ppm.

Rawat and Mathaphal (1981) reported that available iron content in soils of Uttar Pradesh varied from 0.4 to 8.4 ppm.

2.1.4 Zinc:

Sharma and Moti Ramani (1969) found that black soils are rich in available and total zinc than alluvial soils of Madhya Pradesh. The available zinc constituted 8.4% of total zinc.

Viets and Lindsay (1973) classed soils containing less than 0.5 ppm as deficient, 0.5 to 1 ppm as marginal and more than 1 ppm as adequate.

According to Kanwar and Randhawa (1974) the surface soils contained maximum amount of available zinc and availability decreased with profile depth.

Analysis of Punjab soils for zinc by Takkar *et al.* (1976) revealed that soils containing less than 0.6 ppm were deficient and 0.6 to 1.2 ppm adequate in available zinc.

Analysing seven soil profiles from different agro-climatic regions of Karnataka, Vasuki (1979) noticed the highest available zinc content in surface soil of Bidar (3.07 ppm) and Khanapur (2.67 ppm) and the lowest in sub-surface soils of Kathalagere (0.01 ppm). The available DTPA extractable zinc content in the surface layers of Hagari (chromustert) and Kallur (Pellusterts) soils were 0.30 and 0.36 ppm, respectively.

Sarora *et al.* (1983) analysing all the 11 soil series profiles from Kapurtala district of Punjab, reported that loamy sand and silty clay loam soils contained 0.28 - 0.52, 0.62 - 1.08 and 1.24 - 1.52 ppm of available zinc in low, medium and adequate categories, respectively.

Kamparia *et al.* (1984) analysed 391 surface soil samples from Gird region and found that available zinc was in the range of 0.1 to 3.04 ppm indicating that 75 per cent of soils analysed were deficient with a critical limit of 0.4 ppm.

Sakal *et al.* (1988) analysed 812 surface (0.15 cm depth) soil samples from old alluvial soils of Bihar. They found that available zinc in these soils ranged from 0.04 to 5.8 ppm with mean and critical values of 0.66 ppm and 0.65 ppm respectively.

Yaduvanshi *et al.* (1988) noticed no specific pattern of available (DTPA extractable) zinc distribution vertically in the profiles. It was increasing with depth in Palampur and decreasing in Farer, Chandir, Jassor and Paraur series of Kangra valley in Himachal Pradesh. The available zinc varied between 0.5 to 3.9 ppm.

2.1.5 Boron:

Berger and Truog (1945) considered hot water soluble boron as a good index of available boron in soils as it gave good correlations with boron uptake by crops.

Rogar (1947) suggested that hot water soluble boron might be of practical value in selecting areas where boron fertilization could show response.

Bendale *et al.* (1951) reported that black soils of Bombay State contained 0.1 to 0.6 ppm of available boron.

Stinson (1953) suggested to use 0.3 ppm hot water soluble boron for sandy soils and 0.5 ppm for heavy soils as the critical levels.

In alluvial soils of Bihar, Mandal *et al.* (1956) observed that water soluble boron content ranged from 0.3 to 2.2 ppm.

Gandhi and Mehta (1958) found that available boron content of normal soils of Gujarat ranged from 0.2 to 1.5 ppm while that in saline soils of Barocla and Saurashtra from 3.0 to 3.5 ppm.

Rayachoudhuri and Datta Biswas (1964) considered 0.1 to 0.5 ppm of hot water soluble boron in soils as the critical limit for most of the agricultural crops in India.

2.2 Response of cotton to soil application of micronutrients

2.2.1 On growth, yield and yield parameters

Patel and Patel (1949) reported the beneficial effect of manganese, zinc and boron on growth, bud and boll formation of Vijaya cotton (*Gossypium hirsutum*).

From the results of field experiments conducted for a number of years on American and Indian cotton varieties, Dastur and Singh (1953) recorded beneficial effect of copper, manganese and zinc, while application of magnesium had no effect on yield. They reported that on the black cotton soils of Indore (pH 8.2) copper increased cotton yield significantly and it was most promising because of its low cost. The application of 20 lb $ZnSO_4$ increased cotton yield in 4 out of 6 years.

Singh (1961 a) indicated that the treatment of soaking of cotton seeds in $ZnSO_4$ solution before sowing, had no influence on either single plant yield or yield per acre of seed cotton. In this connection, it may be pointed out that the soil in which the trial was conducted, was not known to be deficient in zinc.

The results of the field experiments conducted at Jullundar, Ludhiana, Abohar, Hansi and Hissar by Kanwar and Randhawa (1967) showed that none of the micronutrients registered a significant effect on cotton yield at Jullandar and Ludhiana. But the application of $ZnSO_4$ at 20 kg per ha to the soil at Hansi and Abohar increased the yields of seed cotton by 15.8% and 19.5% to 41.7% respectively. At Abohar, the response of foliar application of $ZnSO_4$ at 2 kg per ha in 150 gallons of water about 60-75 DAS, was highly significant. It resulted in an increase of yield by 57 per cent. Substantial increases were also recorded by both soil and foliar application of Mn at Hansi and Hissar. Anderson and Fred (1968) reported that yield and earliness of harvest benefitted from higher levels of Mn (4.46 kg/ha) and boron (0.89 kg/ha).

Dubey and Singh (1969) reported that zinc in the form of $ZnSO_4$ at 30 kg per ha along with normal dosage of N, P and K increased the yield under rainfed conditions. Yield increase was 11% over control. However, foliar spray decreased the yield levels, but not significantly.

Nageshwara Rao (1977) reported that soil application of Mg, B and Zn increased the seed cotton yield by 16, 26 and 21 per cent, respectively.

Varma *et al.* (1984) reported that all the micronutrients (Zn, B, Mn, Cu, Mo and Fe) increased the yield of capsularis jute in the ran e of 9.22 to 53.3% while in olitorius jute, Fe, Zn, Mo and Cu increased the yield in the range of 8.21 to 36.4 per cent.

Sharma *et al.* (1988) was of the opinion that application of zinc increased the number of bolls per plant, boll weight and seed cotton yield. Effect on plant height was not significant.

Kashyap *et al.* (1988) observed that Zn at 10 ppm produced the maximum dry matter of all plant parts of both genotypes at squaring and flowering stages. Higher Zn levels showed a detrimental effect on Zn content in different plant organs.

Srivastava and Singh (1988) reported that the seed cotton yield increased linearly due to N and Zn upto 80 kg N and 50 kg $ZnSO_4$ per ha respectively. Both N and Zn influenced the number of bolls and yield per plant. A response of 11.31 kg and 8.9 kg seed cotton per ha due to $ZnSO_4$ applied at 25 kg per ha was observed in 1982 and 1983, respectively.

Kumar and Gupta (1989) observed that soil application of $ZnSO_4$ at 20 kg per ha was better than foliar spray. Zinc application concentration in leaves at flowering increased significanly with Zn application. The Zn content in leaves in the foliar application was higher than the soil application due to more active absorption and translocation.

2.2.2 Fibre properties

Hegab et al. (1983) reported that using P_2O_5 and $ZnSO_4$ increased the seed cotton per feddan and lint grade, seed index and lint index were non-significant. Micronnaire value, flat bundle strength and yarn strength improved significantly.

Varma et al. (1984) showed that application of micronutrients gave some increases in fibre yield of jute when applied with NPK but these increases were non-significant. All the micronutrients (Zn, B, Mn, Cu, Mo and Fe) increased the fibre yield of capsularis jute in the range of 9.22 to 53.3% while in olitorius jute, Fe, Zn, Mo and Cu increased the fibre yield in the range of 8.21 to 36.4%.

Srivastava and Singh (1988) reported that neither N nor Zn significantly affected the ginning per cent, lint index and staple length.

Azab and El-Halawany (1989) reported that micronnaire and pressely strength values were not affected by micronutrient application and there was no clear effect on seed index or lint percentage.

Khodzhaev and Stenyagina (1989) from Uzbekistan reported that the soil and seed treatment with $CuSO_4$ + $MnSO_4$ increased the fibre length of cotton compared with NPK alone.

2.3 Response of cotton to foliar application of micronutrients

Foliar application is practiced whenever nutrient uptake through the plant roots is restricted. The restriction may be due to either plant or soil limitations. Eventhough the effectiveness of a unit of foliar applied nutrient may be higher than that for soil application (Gray, 1977); attempts to supply the major nutrient requirements by foliar application are usually not successful due to higher rates and repeated applications which cause foliage scorching and also become expensive. However, spraying micronutrients on foliage is a widely used practice in some areas.

Spraying of Fe, Zn, Mn, Cu, Bo and Mo compounds has been extensively used to prevent nutritional disorders in crops (Gray, 1977). The most common micronutrient deficiency corrected by foliar spraying in arid regions is iron. The amounts of micro-nutrients needed for correction of disorders are relatively less and concentrations of spraying solutions are rather low. Therefore, foliar spray with these nutrients is often much more efficient than soil application.

The most common salts used in spraying solutions are - sulphates of Fe, Zn, Mn, Cu and Mg, sodium borate and ammonium molybdate. However, research on foliar method of fertiliser application is increasing.

2.3.1 On growth, yield and yield parameters

Ahlawat (1974) conducted experiment on SS-265 and 320 F (both *Gossypium hirsutum* L.) at two experimental sites where Zn applied at 10 kg per ha did not affect the yield significantly. However, mean yields increased by 12% over control. Here foliar application proved better (4%) than soil application. Zn application failed to affect the plant height, number of branches, bolls per plant and quality characters like halo length, GOT and seed index.

Nageswara Rao (1977) recorded higher seed cotton yield due to foliar sprays of Mg (18-33%), Zn (29%) and B (32%) than soil applications which gave 16, 21 and 26 per cent, respectively.

El-Gharieb *et al.* (1986) reported that the increase of lint yield ranged from 7.86 kenter (157 kg lint) per feddan (0.42 ha) with 0.2% Fe + 0.2% Mn to 9.73 kenter/feddan. With 0.2% Zn, 100-seed weight ranged from 11.4 to 12.4 g. Aplication of iron markedly increased the number of opened bolls per plant and consequently the yield of kapas.

Ebelhar (1988) observed that harvest plus at a total rate of 20, 30, 40 or 60 lb/acre applied biweekly, increased the mean seed cotton yield but there was no significant difference between treatment and control yields. Foliar application of harvest plus delayed maturity slightly but not significantly.

Sarour et al. (1988) revealed that foliar application of 4% urea single or in combination with mixture of micronutrients gave the highest dry matter and largest leaf area per plant and LAI. No significant effect on plant height, number of flowers, squares and open bolls per plant and seed cotton yield per plant were recorded by application of mixture of micronutrients in combination eith either urea or super phosphate. All foliar spraying materials increased significantly the fruit set per cent while decreased the shedding per cent when compared with control.

Azab and El-Halawamy (1989) showed that application of micronutrients (particularly Fe) increased the leaf chlorophyll content and generaly increased carotenoid content. Internode length increased with Zn or Mn + Zn application. Micronutrient application had no effect on number of nodes, or sympodia/plant but gave small non-significant increases in number of flowers and open bolls per plant and in percentage boll setting. Boll weight and seed index and yield/plant increased with micronutrient application.

Sawan et al. (1989) observed that seed yield per plant, seed viability and seedling vigour increased with increasing N rate and application of Ca, Cu, Zn, Fe or Mn. Seed index increased with increasing N rate along with the application of Cu, Fe or Mn.

2.3.2 Fibre properties

Sawan et al. (1989) indicated that N levels and Ca did not affect the fibre properties whereas appliation of Cu, Zn or Fe increased the 2.5% span length over control.

2.4 Relative efficacy of soil and foliar application of micronutrients

2.4.1 On growth, yield and yield parameters

The deficiencies of Mn in beet-root (Wallace and Ogilvie, 1941) and peas and boron in turnips were very readily corrected by foliar spray than by soil dressing.

In respect of Mn application to onions, spraying appeared to be a more efficient method than soil application (McCall and Davis, 1953).

Tikande (1983) reported that soil application of Zn (10 and 20 kg/ha) gave significantly higher grain and fodder yield of sorghum over control, whereas one foliar application of 1% Zn was found superior to that applied twice or through soil as far as grain and fodder yields were concerned.

Sharma and Gupta (1989) reported that on a soil containing 0.48 ppm available Zn, 25-50 kg/ha $ZnSO_4$ applied, broadcast or drilled or a filiar spray of 0.5% $ZnSO_4$ increased the seed cotton yields by 1.8 - 15; 2.5 - 7.5 and 6.8 per cent, respectively.

Mitra and Jana (1991) stated that among the methods of 'B' application, half soil + half foliar produced significantly more effective tillers which in turn gave 6.6 and 8.8% higher grain yield of wheat than full soil and full foliar methods of application, respectively.

Mortvedt (1991) reported that correction of Fe chlorosis is done mainly by foliar sprays because soil applications generally are ineffective, especially for annual crops.

2.4.2 <u>Quality characters</u>

Kamalanathan <u>et al</u>. (1966) reported that $FeSO_4$ (both soil and foliar) tended to increase the yield of seed cotton in Coimbatore. They observed that foliar as well as soil application of $FeSO_4$ induced fineness, but the strength of fibre was not influenced.

Effect of N fertilization and foliar application of micro-nutrients on cotton yield and fibre quality have been widely studied (Karev, 1980).

Maggag (1987) observed that when the 15 year old grape vines were sprayed with 0.1 or 0.2% boric acid one week before full bloom and again two weeks later in 2 year trials, bunch weight, 100 berry volume and TSS content were increased and acidity was reduced. 0.2% boric acid gave generally better results than lower concentrations.

Mann and Takkar (1987) reported that orange juice and ascorbic acid content increased with increased Zn concentration in the sprays.

Varma <u>et al.</u> (1987) showed that cane juice quality and economic viability were maximum when 'tracel-1' (containing K, S, Fe, Mn, Zn, Cu, Bo, Mg and Mo) was sprayed at 75 (3.75 kg/ha), 105 (10 kg/ha) and 135 (10 kg/ha) days after planting.

Ziolek and Ziolek (1987) indicated that trace elements did not affect the soybean protein content, whose yield was increased by seed yield increase. The amino acid composition of the protein depended on the variety more than the fertilizers.

2.5 Uptake of N, P_2O_5 and K_2O

Published literature on the effect of different micronutrients on the uptake of N, P_2O_5 and K_2O on cotton is not available. However, that in case of other field crops like jowar, mulberry and sunflower is reviewed below.

2.5.1 Uptake of N

Kene (1975) observed that the application of Fe had increased the N uptake over NPK alone.

Viswanath (1979) observed that N uptake of mulberry plant was not very much influenced by foliar spray of micronutrients, but however Fe sprayed plots had highest N uptake.

Gangadhar (1989) working with sunflower indicated that the lowest uptake of N was observed in 20 kg borax/ha, however in $FeSO_4$ applied treatments, significant difference was noticed as compared to NPK alone.

2.5.2 Uptake of P_2O_5

Kene (1975) indicated that the total uptake of P_2O_5 was higher in Fe applied treatment than in NPK only, the difference between them being non-significant.

Vishwanath (1979) observed that Zn, Mn and Fe sprays were fairly high in P_2O_5 uptake.

Gangadhar (1989) noticed non-significant difference in the uptake of P_2O_5 from the various micronutrient treatments, however numerically higher uptake of P_2O_5 (11.96) was in 20 kg/ha $CuSO_4$ application. The uptake of P was found to decrease with soil application of $ZnSO_4$, $MnSO_4$ and borax (8.66, 9.40 and 8.51 kg/ha, respectively).

2.5.3 Uptake of K_2O

Kene (1975) indicated that the application of Zn or Mn either alone or in combination significantly increased the total uptake of K_2O per ha over NPK alone.

Viswanath (1979) observed that Mn at both levels (2.5 and 5.0 kg/ha) gave highest uptake of K_2O followed by foliar spray of $FeSO_4$.

Gangadhar (1989) observed significant differences in K_2O uptake in the whole plant (sunflower) at 60 DAS. Both the levels of $ZnSO_4$ (25 and 50 kg/ha), $FeSO_4$ (25 and 50 kg/ha), $MnSO_4$ (12 and 24 kg/ha) and $CuSO_4$ (10 and 20 kg/ha) showed significant increase in the uptake of K_2O with increased application of respective compounds.

CHAPTER - III

MATERIAL AND METHODS

III. MATERIAL AND METHODS

A field experiment was conducted to study the 'Response of cotton to soil and foliar application of micro-nutrients under rainfed conditions' during 1991-92 cropping season, on medium black cotton soil of ARS, Dharwad farm. The details of the materials used and techniques adopted in the course of investigation, are described below

3.1 Experimental site

The experiment was conducted at ARS, Dharwad farm, Dharwad (Karnataka) which is situated 4 km to the east of Dharwad city on Dharwad - Navalgund road. Dharwad is situated in the assured rainfall tract of zone number 8 of region-IV. It lies between 15°-17' north latitude and 76°-46' east longitude and has an altitude of 678 m above mean sea level (MSL). The experiment consisted of 14 treatments, laid out in randomised block design with three replications using the newly released bollworm tolerant variety 'Abadhita' (*Gossypium hirsutum* L.).

3.2 Soil and its characteristics

The experiment was laid out in plots 9 and 10 of 'C' block consisting of medium black clayey soil. Composite soil samples were drawn from the samples collected from 0-15 cm and 15-30 cm depth in each replication before sowing and were analysed for physical and chemical properties, the results of which are presented in Appendix-I along with the methods employed.

The soil of experimental site is classified as typic chromustert clayey in texture, containing 61.52 to 62.04 per cent of clay in different layers. Values for coarse sand, fine sand and silt ranged between 5.42 to 7.64, 9.40 to 11.50 and 17.30 to 17.68 per cent, respectively.

The pH of surface soil was 8.0 (1:2.5 soil water extract) and an electrical conductivity of 0.29 dSm^{-1}. The cation exchange capacity for the same surface soil was found to be 60.4 c.mol kg^{-1} and organic carbon 0.50 per cent.

The analysis for available status of important nutrients indicated that the soil contained low amounts of available nitrogen (218 kg ha^{-1}) and available phosphorus (26.5 kg ha^{-1}) and adequate in available potassium (371.4 kg ha^{-1}).

3.3 Mechanical analysis of soil

Mechanical analysis was carried out by International Pipette Method as out lined by Piper (1950).

3.3.1 Soil pH

Soil pH was determined in 1:2.5 soil water suspension, as described by Jackson (1967) using pH meter (Model LI-IOT) of Elico.

3.3.2 Electrical conductivity (EC)

The EC of the soil samples was estimated in supernated liquid of 1:2.5 soil water suspension using conductivity bridge (Model C 1182 T).

3.3.3 Calcium carbonate

Free $CaCO_3$ content of the soil was estimated by acid neutralisation method as described by Piper (1950).

3.3.4 Organic carbon

Organic carbon was estimated by Walkey and Black's wet oxidation method as described by Jackson (1967).

3.3.5 Cation exchange capacity (CEC)

The CEC of the soil was determined by sodium saturation method (Black, 1965) and was expressed as c mol/kg.

3.3.6 Available nitrogen

Subbaiah and Ajija's (1956) alkaline permanganate method was employed for available N estimation and was expressed as kg ha^{-1}.

3.3.7 Available phosphorus

Available phosphorous was estimated by Olsen's Method (Black, 1965) and was expressed in kg ha^{-1}.

3.3.8 Available potash

Available K was determined in 1:5 ammonium acetate extractant of soil using Flame Photometer (Black, 1965) and was expressed in kg ha^{-1}.

3.3.9 Hot water soluble boron

Hot water soluble 'B' was estimated by adopting the procedure given by Berger and Truog (1939) and modified by Wear (1965). Air dried soil and 0.01 M $CaCl_2$ solution was boiled for 5 minutes in boron free conical flask with a reflux condenser attachment, filtered and determined 'B' content by Carmine-Sulphuric Acid method.

3.3.10 Available zinc, iron, copper and manganese

Aailable Zn, Cu, Mn and Fe were determined by shaking 10 g of soil with 20 ml DTPA extractant (0.005 M diethylene, triamine, pentacetic acid + 0.01 M $CaCl_2$ and 0.1 M triethonol amine adjusted to pH 7.3) for 2 hours and filtered. The concentration of Zn, Cu, Mn and Fe were lead to Shimadza atomic absorption spectro-photometer model AA-630-11, using suitable standards and cathode lamps for each element (Lindsay and Narvell, 1978).

3.4 Weather conditions

Meteorological data for the year 1991-92 and the mean of previous 25 years recorded at the Meteorological Observatory of ARS, Dharwad are presented in Table-1 and depicted in Fig.1 and 2.

The annual rainfall of the past 25 years from 1967-91 is 765 mm with 97 rainy days. Total rainfall received during the year (1991-92) was 1190 mm as against the normal rainfall of 765 mm (Table-1) i.e., an excess of 425.5 mm (37%). The number of rainy days was 83 against the normal of 97 days, i.e., less by 14. Most of the rainfall was received from June to October. Among these months, July received the highest rainfall of 160.4 mm with 23 rainy days.

Thus, it can be seen that though the total rainfall received was more, the number of rainy days was less to show that the intensity of rainfall was more. In addition to the heavy rainfall, there was continuous cloudy weather for four months (June-October) which resulted in excessive vegetative growth and delayed reproductive phase.

The incidence of pests and diseases was less and they were controlled effectively by timely plant protection sprays. Hence, due to good rainfall conditions and less of pest-disease problems, the yield obtained is more than the average.

Table-1 : Monthly meteorological data for the year 1991-92 and the average of past 25 years recorded at the Meteorological Observatory of ARS, Dharwad

Months	Rainfall (mm)		Deviation from normal	Mean air temperature(°C)			
	1991-92	1967-91		Maximum		Minimum	
				1991-92	1967-91	1991-92	1967-91
1991							
April	119.1 (8)	42.5 (3)	+76.6 (+5)	35.16	39.0	24.94	16.50
May	140.7 (8)	97.5 (8)	+43.2 (=)	35.67	39.2	24.43	16.70
June	355.6 (13)	98.4 (13)	+257.2 (=)	30.06	29.5	23.63	18.10
July	131.7 (17)	160.4 (23)	-28.7 (-6)	27.14	27.8	21.67	18.60
August	119.4 (17)	83.2 (21)	+36.9 (-4)	26.87	28.2	20.58	18.00
September	108.8 (10)	103.2 (12)	+05.6 (-2)	31.15	30.1	22.44	16.10
October	181.7 (7)	129.9 (11)	+51.8 (-4)	32.37	32.9	23.27	14.30
November	15.0 (2)	37.4 (3)	-22.4 (-1)	30.66)	32.1	22.66	9.80
December	0.0 (0)	9.5(0.8)	-9.5(-0.8)	29.83	23.8	18.27	9.50
1992							
January	0.0 (0)	-	-	30.56	29.5	16.59	10.90
February	18.0 (1)	0.08(0.2)	+17.92(0.8)	30.80	32.9	16.40	11.80
March	0.0 (0)	3.0 (0.4)	-3.0 (-0.4)	31.00	35.2	16.90	16.40
Total/ mean	1190.0 (83)	765.0 (97)		30.94	32.3	20.98	16.60

NB : Figures in parentheses denote number of rainy days

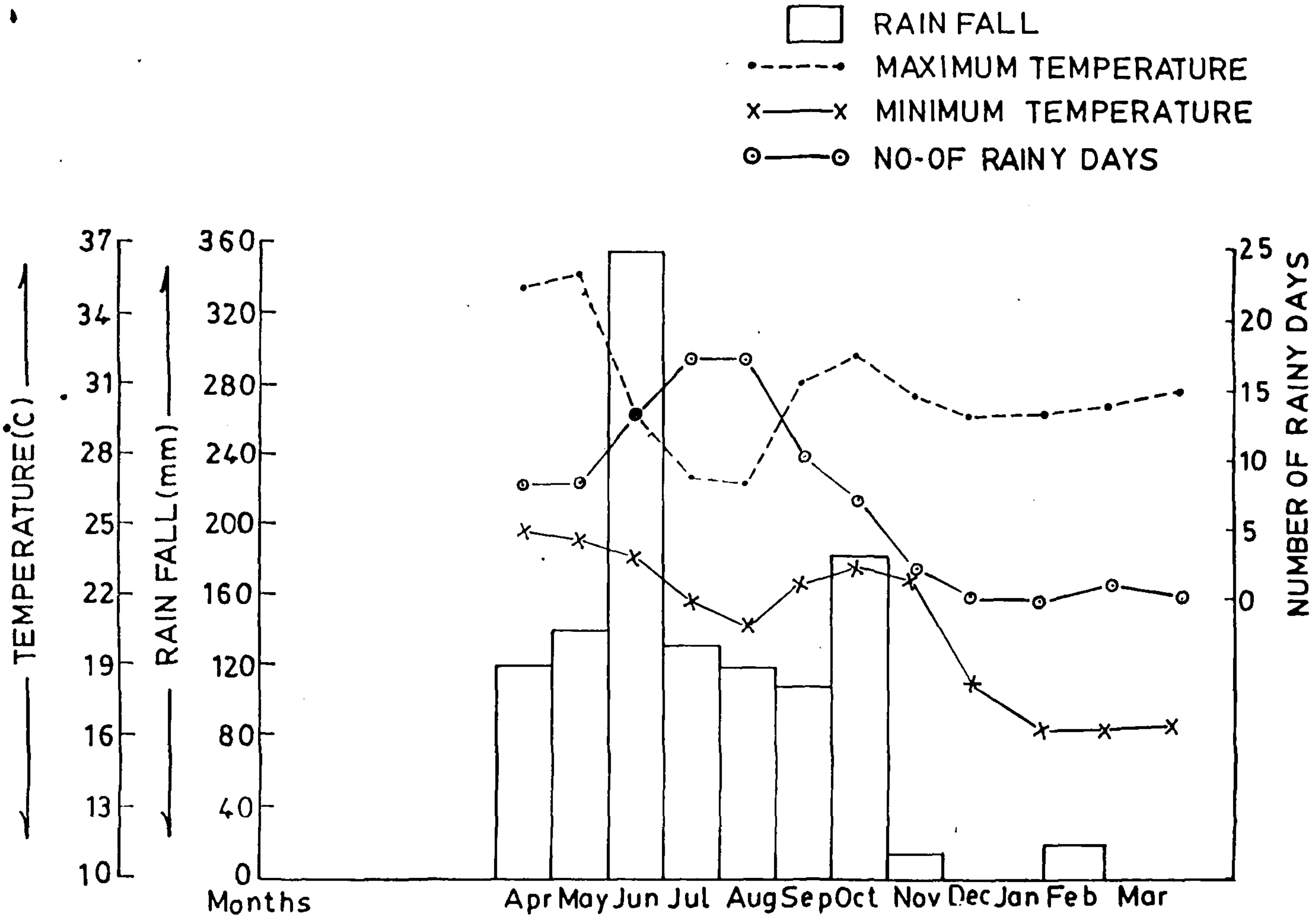

FIG:1-METEOROLOGICAL DATA OF ARS DHARWAD FOR THE YEAR 1991-92

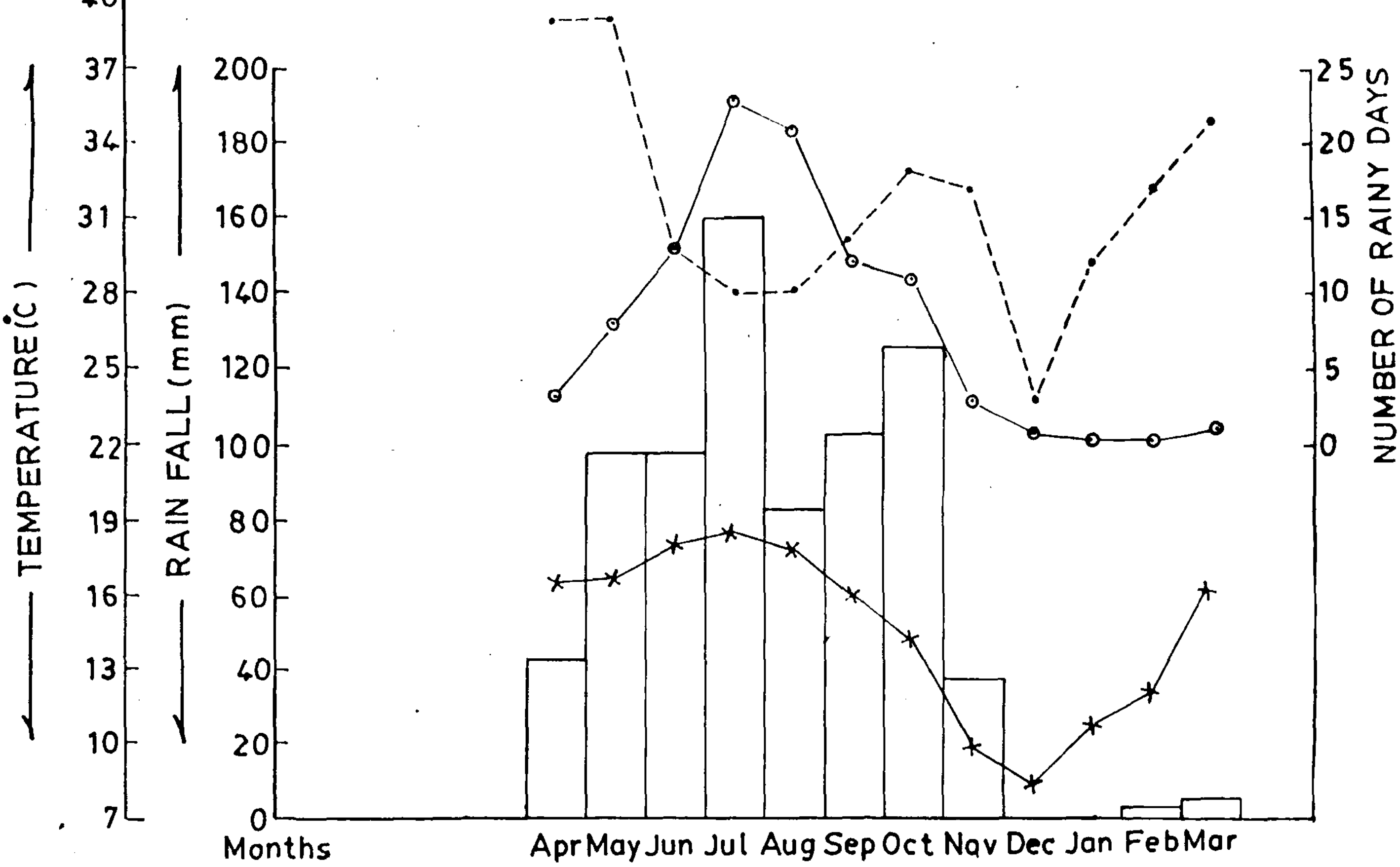

FIG:2-METEOROLOGICAL DATA FOR AVERAGE OF 25 YEARS (1967-1991)

3.5 Previous crop on the experimental site

During the year 1990 kharif, groundnut (Spanish Improved) and in rabi, bengal gram (A-1) were grown on the experimental plot by adopting the recommended Package of Practices for seed purpose.

3.6 Experimental details

3.6.1 Treatments

There were 14 treatments comprising of soil and foliar application of micronutrients, laid out in a randomised block design

Sl. No.	Treatments	Method of application
1	$CuSO_4$ @ 20 kg/ha	Soil application
2	$MnSO_4$ @ 20 kg/ha	Soil application
3	$FeSO_4$ @ 20 kg/ha	Soil application
4	$ZnSO_4$ @ 20 kg/ha	Soil application
5	Borax @ 10 kg/ha	Soil application
6	Combinations of all the 5 nutrients	Soil application
7	$CuSO_4$ @ 5 kg/ha in two equal splits (60 and 90 DAS)	Foliar spray
8	$MnSO_4$ @ 5 kg/ha in two equal splits (60 and 90 DAS)	Foliar spray
9	$FeSO_4$ @ 5 kg/ha in two equal splits (60 and 90 DAS)	Foliar spray
10	$ZnSO_4$ @ 5 kg/ha in two equal splits (60 and 90 DAS)	Foliar spray
11	Borax @2.5 kg/ha in two equal splits (60 and 90 DAS)	Foliar spray
12	Combination of all the 5 nutrients in two equal splits (60 and 90 DAS)	Foliar spray
13	Water spray - control	Foliar spray
14	Absolute control	-

3.6.2 Design and plan of layout

The experiment was laid out in R.B.D. with three replications as depicted in Fig.3.

3.6.3 Plot size

Gross and net plot sizes adopted were as under:

Gross plot .. .. 5.4 x 6.0 m
Net plot .. .. 3.6 x 4.8 m

3.6.4 Variety

'Abadhita (JK-276-4) a newly released (1989) cotton variety belonging to *Gossypium hirsutum* L. was used as the test variety.

3.6.5 Spacing

The recommended spacing of 60 x 30 cm was adopted.

3.7 Cultural operations

3.7.1 Preparation of land

The land was ploughed once with the help of a tractor after the harvest of previous rabi crop of bengalgram. This was followed by harrowing thrice and smoothening with wooden plank to prepare a fine seed bed. Plots were laid out as per the plan well in advance of sowing of cotton.

3.7.2 Fertilizer application

Weighed quantities of N, P_2O_5 and K_2O at a common dose of 40-20-20 kg/ha were mixed with the required quantities (Appendix-II) of micronutrients (Cu, Mn, Fe, B and Zn) and were applied directly to the soil by hand by opening

LEGEND

Treatments	Details
1	$CuSO_4$ at 20 kg/ha, soil application
2	$MnSO_4$ at 20 k /ha, soil application
3	$FeSO_4$ at 20 kg/ha, soil application
4	$ZnSO_4$ at 20 kg/ha, soil application
5	Borax at 10 kg/ha, soil application
6	Combination of all five, soil application
7	$CuSO_4$ at 5 kg/ha, foliar sprays at 60 and 90 DAS in two equal splits
8	$MnSO_4$ at 5 kg/ha, foliar sprays at 60 and 90 DAS in two equal splits
9	$FeSO_4$ at 5 kg/ha, foliar sprays at 60 and 90 DAS in two equal splits
10	$ZnSO_4$ at 5 kg/ha, foliar sprays at 60 and 90 D S in two equal splits
11	Borax at 2.5kg/ha, foliar sprays at 60 and 90 DAS in two equal splits
12	Combinations of all five, foliar sprays at 60 and 90 DAS in two equal splits
13	Water spray, control
14	Absolute control

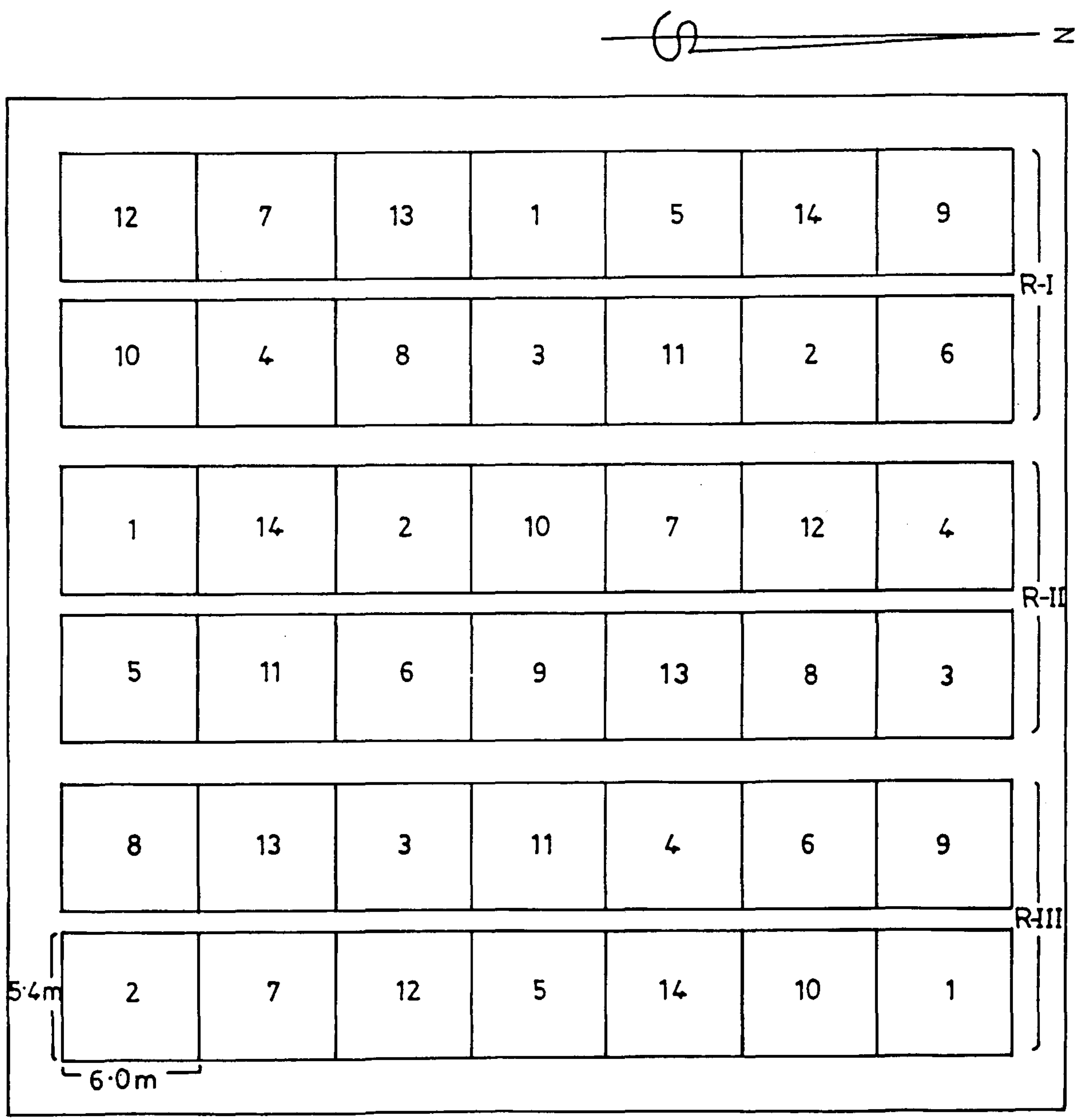

FIG:3–PLAN OF LAYOUT.

8-10 cm deep furrows by hand-drawn wooden plough, before three days of sowing.

For foliar application, micronutrients were sprayed on the crop in two equal doses at 60 DAS (square formation) and 90 DAS (peak flowering) (Appendix-II).

3.7.3 Seeds and sowing

Cotton seeds were treated with bavistin fungicide at 3 g/kg of seed as a preventive measure against soil-borne pathogens. The crop was sown on 14th July, 1991 by hand dibbling two to three seeds per hill with 60 x 30 cm spacing. After 20 days of sowing, seedlings were thinned by leaving two seedlings per hill. Final thinning was done at 30 days after sowing to maintain only one seedling per hill.

3.7.4 After care

Three hand weedings (30, 60 and 90 DAS) were carried out during the crop growth. Intercultivation was taken up once before first weeding and second one before second weeding.

3.7.5 Plant protection

The schedule of plant protection measures taken up during the crop growth period is given in Appendix-III.

3.7.6 Cotton picking

Harvesting of seed cotton was done in three pickings viz., 22.12.1991 (160 DAS), 10.1.1992 (178 DAS) and 3.2.1992 (198 DAS) as ring and net plots, separately.

3.8 Collection of experimental data

3.8.1 Sampling procedure

Five plants per plot were randomly selected for recording various growth and yield parameters. In addition, two plants per plot were randomly selected from the row next to border on either side for recording dry matter accumulation at 45, 75, 105 and 135 DAS stages.

3.8.2 Growth parameters

3.8.2.1 Plant height

The plant height at each stage was recorded from the base of the plant to the growing tip and expressed in cm as the average per plant.

3.8.2.2 Number of monopodial branches per plant

The number of monopodial branches per plant was recorded at three stages (75, 105 and 135 DAS) and the average was worked out.

3.8.2.3 Number of sympodial branches per plant

The number of sympodial branches per plant was recorded at three stages as mentioned above and the average was worked out.

3.8.2.4 Number of leaves per plant

The number of green leaves per plant was recorded at four stages and the average was worked out.

3.8.2.5 Dry matter production and accumulation

The pattern of dry matter production and acomulation in leaf, stem and reproductive parts was studied. The two randomly selected plants were separated into leaf, stem and reproductive parts and were dried at 60°C in hot air oven to get constant weight and oven dry weight was recorded as g per plant separately for all parts.

3.8.2.6 Leaf area per plant (LA)

Leaf area per plant was measured by disc method. Leaves from the two plants taken for sampling, were separated from the plants. Twenty leaves were taken at random and 20 discs were obtained with the help of a cork borer. The discs and the remaining leaf blades were oven dried, their dry weights were recorded and leaf area was calculated by the formula given by Johnson (1967).

$$LA = \frac{W_a \times A}{W_d}$$

where,

LA = Leaf area (dm^2)

W_a = Weight of all leaves (inclusive of the weight of 20 discs) in g.

W_d = Weight of 20 discs in g.

A = Area of 20 discs in dm^2

3.8.2.7 Leaf area index (LAI)

The leaf area index was worked out by dividing the leaf area per plant by the land area (spacing) occupied by that plant. The following formula given by Sestak *et al.* (1971) was used for working out LAI.

$$LAI = \frac{A}{P}$$

where,

A = Leaf area in dm^2

P = Land area or spacing (dm^2) occupied by the plant

3.8.2.8 Absolute growth rate (AGR)

It was calculated by using the formula of Watson (1952) as given below and expressed in g per plant per day.

$$AGR = \frac{W_2 - W_1}{t_2 - t_1}$$

where,

W_1 = dry weight (g) of the plant at time t_1

W_2 = dry weight (g) of the plant at time t_2

3.8.2.9 Relative growth rate (RGR)

It is the rate of increase in dry weight per unit dry weight per unit time and is expressed as g per g per day. It was calculated by the following formula of Blackman (1919).

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

where,

W_1 and W_2 = dry weight of the plant in g at time t_1 and t_2, respectively

3.9 Yield and yield components

3.9.1 Seed cotton yield per ha

Seed cotton from the net plot was picked separately from all the treatments every time and the yield per hectare was worked out by suitable conversion factor based on net plot yield (including five random plants and ten bolls) of all the three pickings.

3.9.2 Seed cotton yield per plant

Seed cotton was picked from the five tagged plants, for each picking. The weight of kapas obtained from these five plants from three pickings was added and then averaged to give the seed cotton yield per plant.

3.9.3 Number of harvested bolls per plant

The bolls picked from the five tagged plants of each treatment were counted during all the three pickings.

To obtain number of bolls picked per plant, the total number of bolls picked was divided by the number of plants from which the bolls were picked and the result is expressed as the number of harvested bolls per plant.

3.9.4 Mean boll weight

Mean boll weight was calculated by dividing total seed cotton yield per plant by the number of bolls harvested per plant.

3.9.5 Number of seeds per boll

The total number of seeds obtained in the seed cotton of ten good opened bolls harvested at the first picking was divided by ten which gave the number of seeds per boll.

3.9.6 Ginning percentage (GP)

The seed cotton from all the pickings was mixed thoroughly and 300 g sample was drawn out. This seed cotton was ginned with hand gin and the ginning percentage was worked out by using the following formula:

$$GP = \frac{\text{Weight of lint (g)}}{\text{Weight of seed cotton (g)}} \times 100$$

3.9.7 Seed index

Seed index is the weight of 100 seeds of cotton, expressed in g, obtained after ginning. Hundred seeds were picked at random after ginning and weighed.

3.9.8 Lint index

Lint index is the weight of lint in g on 100 seeds of cotton. It was calculated by using the following formula.

$$\text{Lint index} = \frac{\text{Weight of 100 seeds x ginning percent}}{\text{100 - ginning per cent}}$$

3.9.9 Fibre properties

Important quality characters mentioned below were determined from composite cotton lint sample drawn from different replications as outlined by Sundaram (1979).

3.9.9.1 Fibre length (mm)

Fibre length was determined by the digital fibrograph. This is an optical instrument with photoelectric cells, scanning parallel cotton fibres. The absorption of light by the fibres is a measure of the number of fibres in the section where the light beam passes through the section. A servo computer connected to the photoelectric cells completes the relative number of fibres corresponding to different span length on the display counter. The value is expressed in mm.

3.9.9.2 Uniformity ratio

Uniformity ratio is derived from the Digital Fibrograph and is the ratio of 50% span length to 2.5% span length, expressed as a percentage.

3.9.9.3 Fibre fineness

Fibre fineness is determined by the micronaire instrument. This instrument gives the measurement of resistance to the flow of air passed at 40 atmospheric pressure, through a plug of cotton 3.24 g in weight. The instrument is designed to indicate the fibre weight per unit length and is calibrated in microgrammes per inch, called the micronaire value.

3.9.9.4 Maturity coefficient

Maturity coefficient can be derived by using the micronaire instrument. Two compressions are done on the same plug using a 3/8" spacer. The difference of two compressions with spacer (WS) and no spacer (NS) give the maturity coefficient.

3.9.9.5 Fibre strength

The instruments used to determine the fibre strength are pressley strength tester/stelometer.

A flat bundle of fibres is placed between a pair of clamps in the instrument and broken.

$$\therefore \quad \text{Strength} = \frac{\text{Breaking length}}{\text{Weight of broken bundle}}$$

Expressed as lbs/mg and g/tex

= lbs/mg x 5.36

3.9.10 Plant analysis for nutrient uptake

The plant samples collected for estimation of dry matter production at 135 days stage were milled to a considerable fineness in a stainless steel grinder and powdered samples were stored in plastic bags. These samples were used for the analysis of nitrogen, phosphorus and potash uptake.

3.9.10.1 Estimation of nitrogen uptake

The nitrogen content in the samples was estimated by micro-kjedhal method (Jackson, 1967) and expressed as percentage on dry weight basis. Nitrogen content was multiplied by the corresponding dry weight per plant and plant population and expressed as uptake in kg per hectare.

3.9.10.2 Estimation of phosphorous uptake

Phosphorous content in plant as a whole, was estimated calorimetrically as suggested by Jackson (1967) by employing vanidomolybdate yellow colour method and colour intensity was read in spectrophotometer. Phosphorous content was multiplied by the corresponding dry weight per plant, population density and expressed as uptake in kg per ha.

3.9.10.3 Estimation of potassium uptake

Potassium content in plant was estimated with the help of flame photometer (Jackson, 1967). Potassium content was multiplied by corresponding dry weight per plant and plant population and expressed as uptake in kg per hectare.

3.9.11 Statistical analysis

Fisher's method of analysis of variance was applied for the analysis and interpretation of the data as given by Panse and Sukhatme (1967).

The level of significance used in 'F' and 't' tests was P = 0.05. Critical difference values were calculated wherever 'F' test was significant.

CHAPTER - IV

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

Results of the experiment conducted during 1991-92 season at the Agricultural Research Station, Dharwad farm, to study the 'Response of cotton Cv. Abadhita (G. hirsutum) to soil and foliar application of micronutrients under rainfed conditions' are presented in this chapter.

4.1 Soil properties

The physical and chemical properties of representative soil samples from the experimental plot are presented in Appendix-I.

The soil of experimental plot is classified as typic chromustert clay in texture, containing 61.52 to 62.04 per cent of clay in different layers. Values for coarse sand, fine sand and silt ranged between 5.42 to 7.64; 9.40 to 11.50 and 17.30 to 17.68 per cent, respectively.

The pH of surface soil was 8.0 and electrical conductivity was 0.29 dSm^{-1}. The cation exchange capacity for the same surface soil was found to be 60.5 mol kg^{-1} and organic carbon 0.50 per cent.

The analysis for available status of important nutrients indicated that the soil contained low amounts of available nitrogen (218 kg/ha) and phosphorous (26.5 kg/ha) while the available potassium was adequate (371.60 kg/ha).

In respect of initial micronutrients status of soil at 0-15 cm depth, Fe (7.4 ppm), Cu (2.29 ppm), Mn (24.13 ppm), B (0.97 ppm) and Zn (2.63 ppm) were recorded whereas at 15-30 cm depth, 2.11, 7.30, 21.23, 0.74 and 1.22 ppm were present, respectively showing that surface layer (0-15 cm) contains higher amounts of micronutrients than the lower layer of 15-30 cm.

4.2 Effect of micronutrients on the growth of cotton plant

4.2.1 Plant height

The data on plant height at 45, 75, 105 and 135 DAS as influenced by soil and foliar application of micronutrients are presented in Table-2 and Fig.4.

At 45 DAS plant height differed significantly among different treatments. Compared with control (15.20 cm) except T_{13}, all the other treatments increased the plant height significantly, the increase in case of T_8 being nearly significant. T_2 viz., $MnSO_4$ (soil application) recorded the highest plant height of 22.2 cm followed by T_5 borax (soil application (21.94 cm), T_{12} (combination foliar) (21.63 cm), T_7 ($CuSO_4$ foliar application) (20.75 cm) and T_4 ($ZnSO_4$ soil application) (20.17 cm) as against 15.20 of absolute control and 16.20 cm of water spray.

At 75 DAS also, treatments differed significantly as regards plant height. Compared with absolute control (62.33 cm) all the treatments except water spray (61.50 cm) recorded

Table-2. Plant height (cm) of cotton as influenced by soil and foliar application of micronutrients.

Treatments	45 DAS	75 DAS	105 DAS	135 DAS
T_1 - $CuSO_4$, 20 kg/ha (soil application)	19.26	73.50	112.33	115.16
T_2 - $MnSO_4$, 20 kg/ha (soil application)	22.20	70.58	102.26	108.50
T_3 - $FeSO_4$, 20 kg/ha (soil application)	19.90	78.83	107.83	113.80
T_4 - $ZnSO_4$, 20 kg/ha (soil application)	20.17	70.16	99.66	111.83
T_5 - Borax, 10 kg/ha (soil application)	21.94	90.50	112.66	115.67
T_6 - Combination of all five elements (soil application)	19.43	76.16	98.67	107.66
T_7 - $CuSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	20.75	70.83	100.83	104.33
T_8 - $MnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	18.20	68.83	96.83	100.00
T_9 - $FeSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	18.79	71.66	109.00	109.99
T_{10} - $ZnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	18.90	70.00	105.33	109.16
T_{11} - Borax, 2.5/kg/ha(foliar spray at 60 & 90 DAS) in 2 equal splits	19.56	71.41	104.00	111.66
T_{12} - Combinations of all five elements (foliar spray at 60 & 90 DAS) in 2 equal splits	21.63	72.00	105.50	115.33
T_{13} - Water spray, control	16.20	61.50	90.16	95.00
T_{14} - Absolute control	15.20	62.33	82.66	91.67
S.Em. ±	1.09	2.27	7.21	5.96
C.D. at 5%	3.17	6.61	20.90	N.S.

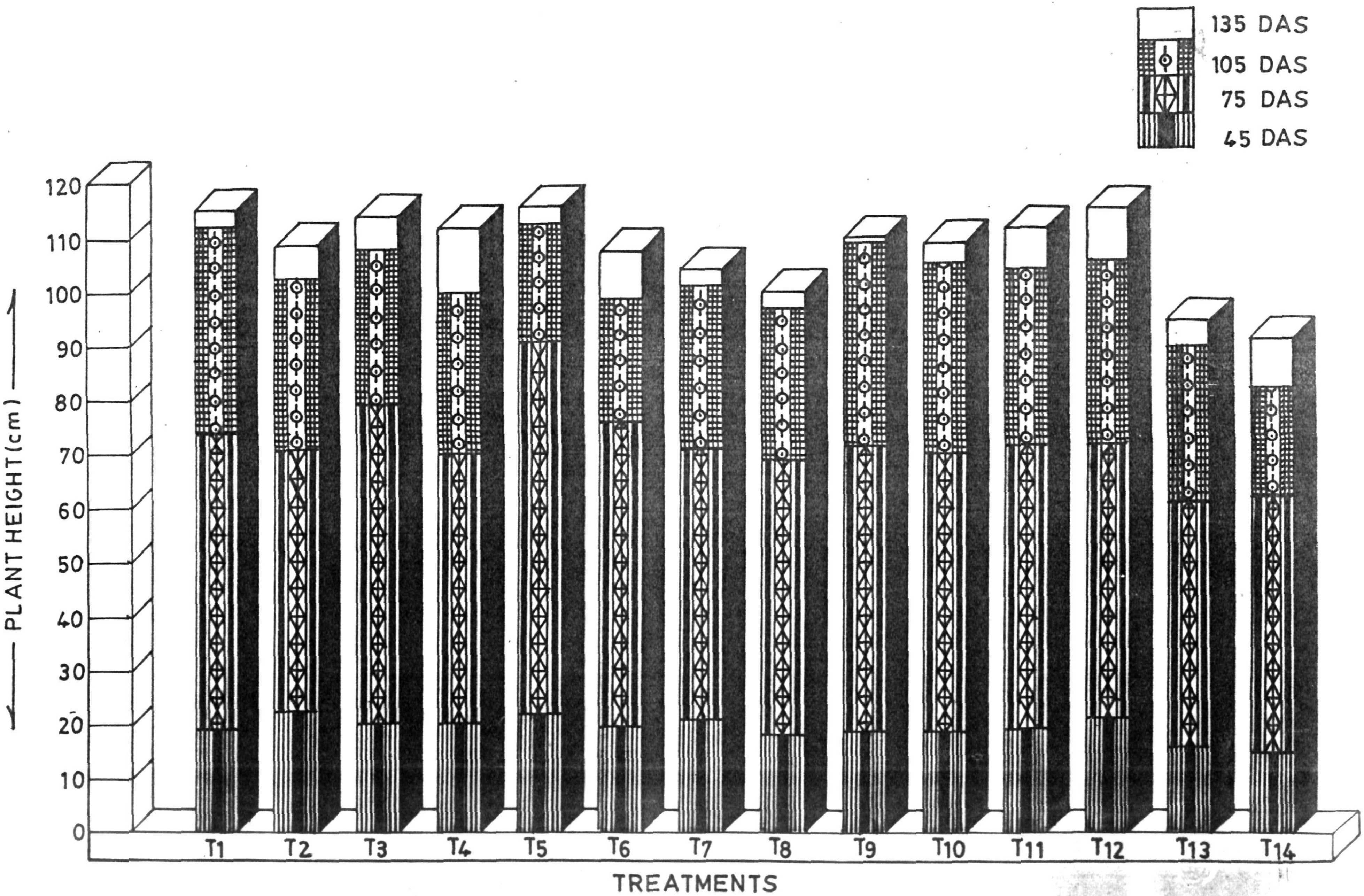

FIG: 4-PLANT HEIGHT (cm) OF COTTON AT DIFFERENT GROWTH STAGES AS INFLUENCED BY SOIL AND FOLIAR APPLICATION OF MICRONUTRIENTS.

significantly higher plant height. The increase in plant height in different treatments over control varied from 6.5 cm to 28.2 cm. T_5 - soil application of borax @ 10 kg/ha recorded the highest plant height (90.50 cm) followed by T_3 - $FeSO_4$ soil application (78.83 cm), T_6 - combination of soil applications (76.16 cm), T_1 - $CuSO_4$ soil application (73.5 cm) and T_{12} - combination of foliar applications (72.00 cm) respectively. Soil application of all the micronutrients increased the plant height over the respective foliar application treatments. However, the increase was significant in case of $FeSO_4$ and borax only.

At 105 DAS, plant height of different treatments differed significantly from control. The increase over control varied from 7.5 cm in T_{13} to 30.0 cm in T_5. Soil application of borax (T_5), recorded the highest plant height of 112.66 cm followed by T_1 - soil application of $CuSO_4$ (112.33 cm), T_9 - foliar application of $FeSO_4$ (109.0 cm), T_3 - soil application of $FeSO_4$ (107.83 cm), T_{12} - combination of foliar applications (105.5 cm) and T_{11} - foliar application of borax (104.0 cm). All these treatments were significantly superior to control. The remaining treatments also increased the plant height, but not significantly. There was not much difference in the plant height between soil and foliar application of micronutrients.

At 135 DAS, there was no significant difference in the plant height of different treatments. However, T_5 - soil application of borax recorded the highest plant height (115.67 cm) followed by T_{12} - combination of foliar spray (115.33 cm), T_1 - $CuSO_4$ soil application (115.16 cm), T_3 - $FeSO_4$ soil application (113.8 cm), T_4 - $ZnSO_4$ soil application (111.83 cm) and T_{11} - borax foliar application (111.66 cm) as against 91.67 cm of absolute control and 95.0 cm of water spray control. In general, plant height was greater in soil application than in foliar application of micronutrients.

4.2.2 Number of monopodia per plant

Data on the number of monopodial branches per plant recorded at 75, 105 and 135 DAS are presented in Table-3.

The effect of soil and foliar application of micronutrients ($CuSO_4$, $MnSO_4$, $FeSO_4$, $ZnSO_4$ and borax) on the number of monopodial branches recorded at all the growth stages, was found non-significant. However, at 135 DAS, $ZnSO_4$ (soil application) recorded the highest number of monopodial branches (4.67) per plant over control (2.50) followed by $FeSO_4$ (soil application), borax (soil application) and combination (soil applications), all having 4.50 per plant.

42.3 Number of sympodial branches per plant

Data on the number of sympodial branches per plant recorded at 75, 105 and 135 DAS are presented in Table-3.

At 75 DAS and 105 DAS, soil and foliar application of micronutrients significantly increased the number of sympodial branches. Whereas at 135 DAS, the effect was non-

Table-3. Number of monopodial (M) and sympodial (S) branches per plant as affected by soil and foliar application of micronutrients under rainfed conditions

Treatments	75 DAS		105 DAS		135 DAS	
	M	S	M	S	M	S
T_1 - $CuSO_4$, 20 kg/ha (soil application)	3.66	9.16	3.33	12.33	4.00	12.66
T_2 - $MnSO_4$, 20 kg/ha (soil application)	2.16	8.66	3.83	11.83	4.00	13.33
T_3 - $FeSO_4$, 20 kg/ha (soil application)	3.00	11.50	3.50	12.00	4.50	12.66
T_4 - $ZnSO_4$, 20 kg/ha (soil application)	2.33	9.00	3.50	11.33	4.67	16.16
T_5 - Borax, 10 kg/ha (soil application)	3.00	10.33	2.83	14.00	4.50	12.17
T_6 - Combination of all five elements (soil application)	3.00	9.55	3.16	13.30	4.50	11.50
T_7 - $CuSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	3.33	9.00	3.33	13.66	3.67	12.33
T_8 - $MnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	2.50	9.33	3.83	12.66	2.83	12.00
T_9 - $FeSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	2.83	9.00	3.66	12.83	4.00	12.16
T_{10} - $ZnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	3.16	9.00	3.33	12.33	3.16	12.00
T_{11} - Borax, 2.5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	2.83	9.16	3.00	12.33	3.67	12.36
T_{12} - Combination of all five elements (foliar spray at 60 & 90 DAS) in 2 equal splits	3.16	9.16	3.33	13.33	3.67	12.33
T_{13} - Water spray, control	2.16	7.33	2.16	9.83	3.00	9.50
T_{14} - Absolute control	2.16	7.66	2.00	9.16	2.50	9.50
S.Em ±	0.38	0.563	0.58	0.84	0.64	0.38
CD at 5%	N.S.	1.63	N.S.	2.43	N.S.	N.S.

significant. At 75 DAS, the highest number of sympodial branches per plant was recorded in soil application of $FeSO_4$ (T_3) (11.5) followed by 10.33 in soil application of borax (T_8) and 9.55 in soil application of combination (T_6) and the rest of the treatments were on par with one another. Non-significant difference was noticed in respect of sympodial branches at 135 DAS. However, highest number of sympodial branches was recorded in soil application of $ZnSO_4$ (16.16) followed by $MnSO_4$ (soil) (13.33) when compared to water spray control and absolute control (both recording 9.50).

4.2.4 <u>Number of leaves per plant</u>

Data on the number of leaves per plant recorded at 45, 75, 105 and 135 DAS are given in Table-4.

At all the four stages of crop growth, significant difference in respect of number of leaves was observed.

At 45 DAS, foliar application of $FeSO_4$ recorded the highest number of leaves per plant (18.16) followed by soil application of $MnSO_4$ (15.00) and foliar application of $MnSO_4$ (14.40) as compared to 10.80 of absolute control.

At 75 DAS, the number of leaves was highest in soil application of combination (97.0) followed by foliar application of $ZnSO_4$ (95.16) as against 55.83 of absolute control.

Table-4. Number of leaves at different stages of cotton Abadhita under rainfed conditions for soil and foliar application of micro-nutrients

Treatments	45 DAS	75 DAS	105 DAS	135 DAS
T_1 - $CuSO_4$, 20 kg/ha (soil application)	14.13	80.16	123.30	43.50
T_2 - $MnSO_4$, 20 kg/ha (soil application)	15.00	82.00	99.50	72.00
T_3 - $FeSO_4$, 20 kg/ha (soil application)	14.13	72.83	133.00	55.50
T_4 - $ZnSO_4$, 20 kg/ha (soil application)	13.88	75.00	118.00	100.83
T_5 - Borax, 10 kg/ha (soil application)	12.33	90.66	131.50	41.50
T_6 - Combination of all five elements (soil application)	13.06	97.00	145.33	62.60
T_7 - $CuSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	13.67	81.83	142.33	108.16
T_8 - $MnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	14.40	83.83	101.33	77.16
T_9 - $FeSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	18.16	81.66	110.83	63.83
T_{10} - $ZnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	12.46	95.16	104.00	80.83
T_{11} - Borax, 2.5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	12.26	78.66	94.83	41.50
T_{12} - Combination of all five elements (foliar spray at 60 & 90 DAS) in 2 equal splits	12.73	78.00	148.00	71.33
T_{13} - Water spray, control	12.13	49.67	63.16	39.16
T_{14} - Absolute control	10.80	55.83	61.83	41.66
S.Em. ±	0.563	4.63	11.81	12.01
C.D. at 5%	1.635	13.46	34.23	35.15

At 105 DAS, the highest number of leaves per plant was recorded in foliar application of combination (148.00) followed by soil application of combination (145.33), foliar application of $CuSO_4$ (142.33) and soil application of $FeSO_4$ (133.00) when compared to 61.83 of absolute control.

At 135 DAS, highest number of leaves per plant was observed in foliar spray of $CuSO_4$ (108.16) followed by soil application of $ZnSO_4$ (100.83) and foliar spray of $ZnSO_4$ (80.83) when compared to control (41.66).

4.2.5 Leaf area per plant (dm^2)

Data on the leaf area per plant of cotton recorded at four different stages (45, 75, 105 and 135 DAS) of crop growth as influenced by soil and foliar application of micronutrients are presented in Table-5.

The differences in leaf area (dm^2) per plant, were not significant at 45 DAS, whereas the treatments differed significantly at 75, 105 and 135 DAS.

At 75 DAS, higher leaf area per plant (41.13 dm^2) was recorded in soil application of $FeSO_4$ (T_3) and the lowest leaf area per plant (23.32 dm^2) was recorded in absolute control. Except soil application of $ZnSO_4$, rest of the treatments recorded significantly higher leaf area than that of absolute control. Leaf area in water spray control (35.99 dm^2) was also significantly higher as compared to absolute control (T_{14}).

Table-5. Leaf area (dm^2) per plant as affected by soil and foliar application of micronutrients under rainfed conditions at different stages

Treatments	45 DAS	75 DAS	105 DAS	135 DAS
T_1 - $CuSO_4$, 20 kg/ha (soil application)	13.78	33.94	41.86	45.07
T_2 - $MnSO_4$, 20 kg/ha (soil application)	15.77	33.07	33.14	38.[illegible]
T_3 - $FeSO_4$, 20 kg/ha (soil application)	14.28	41.13	32.75	34.41
T_4 - $ZnSO_4$, 20 kg/ha (soil application)	14.29	28.58	28.54	34.07
T_5 - Borax, 10 kg/ha (soil application)	13.86	39.87	39.09	37.92
T_6 - Combination of all five elements (soil application)	17.73	35.70	45.98	36.28
T_7 - $CuSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	14.93	31.39	40.98	45.57
T_8 - $MnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	20.71	34.30	30.33	44.11
T_9 - $FeSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	13.56	34.89	34.97	47.37
T_{10}- $ZnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	14.37	31.64	36.11	47.96
T_{11}- Borax, 2.5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	16.72	31.[illegible]	29.84	39.50
T_{12}- Combinations of all five elements (foliar spray at 60 & 90 DAS) in two equal splits	18.40	35.99	27.66	41.73
T_{13}- Water spray, control	15.35	35.99	17.77	31.42
T_{14}- Absolute control	12.37	23.32	16.70	31.28
S.Em. ±	1.94	2.46	2.03	3.17
C.D. at 5%	N.S.	7.13	5.90	9.18

At 105 DAS, leaf area per plant was highest in soil application of combination (45.98 dm^2) as compared to 17.77 dm^2 of water spray control. Significant increase in leaf area was observed both with soil and foliar application of various micronutrients as compared to water spray as well as absolute control.

At 135 DAS, foliar application of $ZnSO_4$ (47.96 dm^2) and $FeSO_4$ (47.37 dm^2) recorded higher leaf area per plant than that of water spray control (31.42 dm^2) and absolute control (31.28 dm^2). Soil application of $CuSO_4$, foliar application of $CuSO_4$, $MnSO_4$ and combination also recorded significantly higher leaf area than that of both water spray and absolute control.

4.2.6 Leaf area index (LAI)

Data on the leaf area index recorded at 45, 75, 105 and 135 DAS as influenced by soil and foliar application of micronutrients are presented in Table-6.

The differences in leaf area index were not significant at 45 DAS. However, at 75, 105 and 135 DAS, leaf area index differed significantly.

At 75 DAS, soil application of $FeSO_4$ (2.285) and borax (2.215) recorded higher leaf area index than absolute control (1.177). Except soil application of $ZnSO_4$, rest of the micronutrient treatments recorded significantly higher leaf area index than water spray and absolute control.

Table-6. Leaf area index of cotton as influenced by soil and foliar aplication of micronutrients under rainfed conditions at different stages

Treatments	45 DAS	75 DAS	105 DAS	135 DAS
T_1 - $CuSO_4$, 20 kg/ha (soil application)	0.765	1.885	2.325	2.503
T_2 - $MnSO_4$, 20 kg/ha (soil application)	0.881	1.837	1.841	2.149
T_3 - $FeSO_4$, 20 kg/ha (soil application)	0.793	2.285	1.819	1.911
T_4 - $ZnSO_4$, 20 kg/ha (soil application)	0.794	1.567	1.585	1.893
T_5 - Borax, 10 kg/ha (soil application)	0.770	2.215	2.172	1.434
T_6 - Combination of all five elements (soil application)	0.985	1.983	2.554	1.737
T_7 - $CuSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	0.829	1.725	2.277	2.365
T_8 - $MnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	1.151	1.905	1.685	2.450
T_9 - $FeSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	0.753	1.938	1.942	2.632
T_{10}- $ZnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	0.798	1.757	2.006	2.664
T_{11}- Borax, 2.5kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	0.929	1.771	1.657	2.184
T_{12}- Combination of all five elements (foliar spray at 60 & 90 DAS) in 2 equal splits	1.022	1.999	1.536	2.873
T_{13}- Water spray, control	0.853	0.890	0.987	1.745
T_{14}- Absolute control	0.667	1.177	0.927	1.668
S.Em. ±	0.108	0.157	0.113	0.151
C.D. at 5%	N.S.	0.455	0.329	0.439

At 105 DAS, application of micronutrients either through soil or foliage, recorded significantly higher LAI, than that of control with soil application of combination, giving the highest LAI (2.554).

At 135 DAS, soil application of $FeSO_4$, $ZnSO_4$, borax and combination, recorded higher but on par LAI than that of control. Foliar application of micronutrients either individually or in combination recorded significantly higher LAI as compared to that of control.

4.2.7 Absolute growth rate (AGR)

Data on the absolute growth rate of cotton (g/plant/day) for different growth periods are presented in Table-7.

Significant differences were observed between 45-75, 76-105 and 106-135 DAS. At 45-75 DAS, highest absolute growth rate was recorded in T_5 - borax (Soil) (1.32) followed by T_6 - combination soil (1.13) and T_1-$CuSO_4$ (soil) (1.0). Absolute growth rate was at its peak between 75-105 DAS. Highest AGR was recorded in T_1-soil application of $CuSO_4$ (2.21) followed by T_7 - foliar application of $CuSO_4$ (2.20), T_{12} - combination foliar (2.04) and T_8 - foliar application of $MnSO_4$ (1.90) when compared to water spray control (0.97). Between 106-135 DAS highest AGR was recorded in soil application of $ZnSO_4$(2.48) followed by T_2 - soil application of $MnSO_4$ (2.10), T_7 - foliar application of $CuSO_4$ (1.60), T_{10} - foliar application of $ZnSO_4$ (1.53) and T_9 - foliar application of $FeSO_4$ (1.32). Soil and

Table-7. Absolute growth rate (g/plant/day) as influenced by soil and foliar application of micronutrients

Treatments	45 - 75 DAS	76 - 105 DAS	106 - 135 DAS
T_1 - $CuSO_4$, 20 kg/ha (soil application)	1.07	2.21	0.32
T_2 - $MnSO_4$, 20 kg/ha (soil application)	0.96	1.47	2.10
T_3 - $FeSO_4$, 20 kg/ha (soil application)	0.95	1.69	1.18
T_4 - $ZnSO_4$, 20 kg/ha (soil application)	0.79	1.27	2.48
T_5 - Borax, 20 kg/ha (soil application)	1.31	1.47	0.15
T_6 - Combination of all five elements (soil application)	1.13	1.64	1.12
T_7 - $CuSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	0.93	2.20	1.60
T_8 - MnSO4, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	0.84	1.90	0.62
T_9 - $FeSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	0.89	1.87	1.32
T_{10}- $ZnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	0.94	1.71	1.53
T_{11}- Borax, 2.5kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	0.90	1.52	0.86
T_{12}- Combination of all five elements (foliar spray at 60 & 90 DAS) in 2 equal splits	0.98	2.04	0.69
T_{13}- Water spray control	0.51	0.97	0.53
T_{14}- Absolute control	0.44	1.12	0.41
S.Em. ±	0.100	0.20	0.41
C.D. at 5%	0.28	0.60	1.23

foliar applied $ZnSO_4$ was able to increase the AGR constantly throughout the cropping period.

4.2.8 Relative growth rate (RGR)

Data on relative growth rate (g/plant) of cotton as influenced by soil and foliar application of micronutrients recorded at 45-75, 76-105 and 106-135 DAS periods are presented in Table-8.

Significant differences of RGR were observed between 45-75 DAS, whereas at 76-105 and 106-135 DAS, differences of RGR were non-significant. At 45 DAS borax (soil) recorded the RGR value of 0.061 followed by $CuSO_4$ (soil) (0.055), combination (soil) (0.051) and combination foliar (0.050) as against 0.038 of water spray and 0.034 of absolute control.

4.3 Dry matter accumulation

4.3.1 Dry matter accumulation in stem

Data on dry matter accumulation in stem are presented in Table-9 and Fig.5.

Dry matter production in stem per plant was significant at 45, 75 and 105 DAS whereas at 135 DAS, it showed non-significant effect.

At 45 DAS, the highest dry weight of stem (2.66 g) was recorded in soil application of $MnSO_4$ (T_2) and differed significantly when compared to control (1.61 g). Treatments T_3, T_5, T_6, T_8, T_{10} and T_{11} also produced significantly higher dry matter in stem. Soil application of $CuSO_4$, water spray control and absolute control were on par with one another.

Table-8. Relative growth rate (g/g/day) as influenced by soil and foliar application of micronutrients at different growth stages of cotton cv. JK-276-4.

Treatments	45 - 75 DAS	76 - 105 DAS	106 - 135 DAS
T_1 - $CuSO_4$, 20 kg/ha (soil application)	0.055	0.032	0.002
T_2 - $MnSO_4$, 20 kg/ha (soil application)	0.045	0.025	0.018
T_3 - $FeSO_4$, 20 kg/ha (soil application)	0.047	0.028	0.011
T_4 - $ZnSO_4$, 20 kg/ha (soil application)	0.040	0.025	0.023
T_5 - Borax, 10 kg/ha (soil application)	0.061	0.025	0.008
T_6 - Combination of all five elements (soil application)	0.051	0.024	0.010
T_7 - $CuSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	0.049	0.034	0.012
T_8 - $MnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	0.042	0.032	0.006
T_9 - $FeSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	0.048	0.031	0.012
T_{10} - $ZnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	0.038	0.028	0.013
T_{11} - Borax, 2.5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	0.047	0.027	0.009
T_{12} - Combination of all five elements (foliar spray at 60 & 90 DAS) in 2 equal splits	0.050	0.032	0.006
T_{13} - Water spray control	0.038	0.027	0.009
T_{14} - Absolute control	0.034	0.032	0.006
S.Em. ±	0.1169	0.040	0.030
C.D. at 5%	0.3389	N.S.	N.S.

At 75 DAS, highest stem dry weight was recorded in soil application of borax (25.6 g) followed by soil application of $CuSO_4$, combination (soil), $MnSO_4$, $FeSO_4$ and foliar application of $CuSO_4$, $ZnSO_4$ and borax. T_9, T_8, T_4 and T_{12} treatments were on par with one another. Combination of micronutrients applied through soil and foliar applications recorded 22.0 g and 18.25 g respectively of dry matter in stem, as against 11.41 g of water spray and 9.83 g of absolute control.

At 105 DAS, significant effect of stem dry matter was observed. Highest stem dry matter was recorded in soil application of $CuSO_4$ (59.75 g) followed by soil application of borax (58.4), foliar a-pplication of $CuSO_4$ (58.0 g), $FeSO_4$ (soil) (51.6 g) and foliar application of $MnSO_4$ (51.25 g), as against 27.5 g of absolute control. Dry matter production in treatments T_3, T_8, T_7, T_5, T_1, T_6 and T_{12} was on par with one another.

At 135 DAS, the results showed statistically non-significant differences in respect of dry matter production in stem. However, numerically higher stem dry matter was recorded in foliar application of $CuSO_4$ (70.0 g) followed by soil application of $MnSO_4$ (67.35 g) when compared to absolute control (27.40 g). Combination treatments of soil and foliar application of micronutrients (T_6 and T_{12}) recorded 58.0 g and 57.30 g dry matter in stem, respectively.

Table-9. Oven dried stem dry matter (g) perplant at different growth stages of cotton for soil and foliar application of micro-nutrients under rainfed conditions

Treatments	45 DAS	75 DAS	105 DAS	135 DAS
T_1 - $CuSO_4$, 20 kg/ha (soil application)	1.75	22.16	59.75	57.30
T_2 - $MnSO_4$, 20 kg/ha (soil application)	2.66	20.83	45.16	67.35
T_3 - $FeSO_4$, 20 kg/ha (soil application)	2.33	18.85	51.60	61.00
T_4 - $ZnSO_4$, 20 kg/ha (soil application)	2.08	17.85	42.70	62.50
T_5 - Borax, 10 kg/ha (soil application)	2.58	25.60	58.40	43.75
T_6 - Combination of all five elements (soil application)	2.33	22.00	49.50	58.00
T_7 - $CuSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	2.16	19.66	58.00	70.00
T_8 - $MnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	2.40	16.83	51.25	51.40
T_9 - $FeSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	2.16	16.66	50.20	56.75
T_{10} - $ZnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	2.24	19.66	42.00	59.00
T_{11} - Borax, 2.5kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	2.33	18.33	41.50	52.35
T_{12} - Combination of all five elements (foliar spray at 60 & 90 DAS) in 2 equal splits	2.16	18.15	44.10	57.30
T_{13} - Water spray, control	1.58	11.41	25.10	34.40
T_{14} - Absolute control	1.61	9.83	27.50	27.40
S.Em. ±	0.20	1.60	4.70	8.86
C.D. at 5%	0.60	4.50	13.60	N.S.

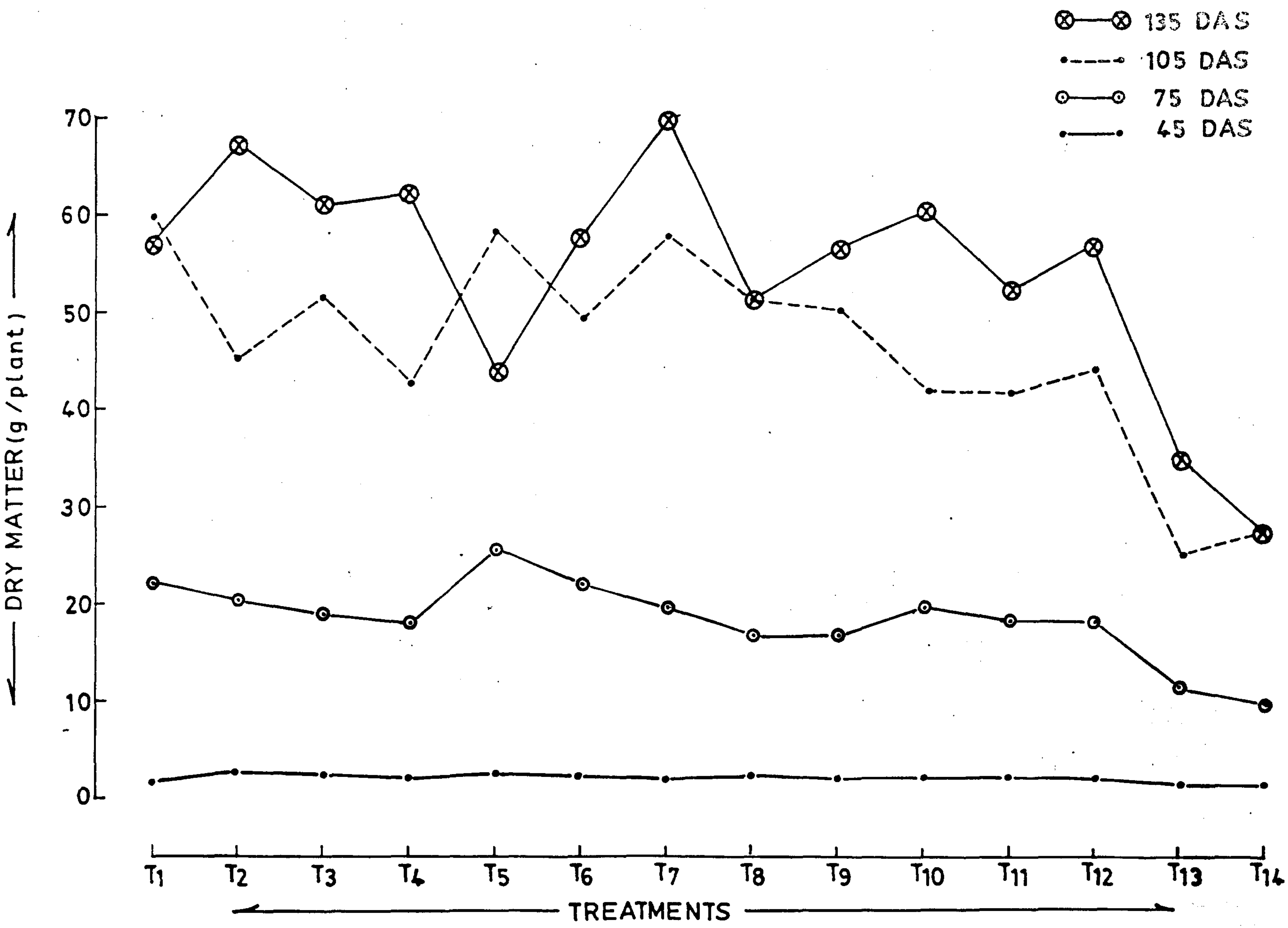

FIG:5-OVEN DRY WEIGHT OF STEM(g/plant) AT DIFFERENT GROWTH STAGES AS INFLUENCED BY SOIL AND FOLIAR APPLICATION OF MICRONUTRIENTS.

4.3.2 Dry matter accumulation in leaves

Data on dry matter accumulation in leaves, recorded at 45, 75, 105 and 135 DAS are given in Table-10 and Fig.6.

Leaf dry weight at 45 DAS showed statistically non-significant differences whereas at 75, 105 and 135 DAS, showed significant differences among the treatments.

At 75 DAS, highest leaf dry matter was recorded by T_5 - borax soil applied treatment followed by treatments T_6, T_3, T_{12} and T_8. At 105 DAS, highest dry weight of leaves was recorded in T_{12} - combination (foliar) followed by T_{10} - $ZnSO_4$ (foliar) (37.50 g) as against 23.00 g of absolute control. At 135 DAS, leaf dry weight started decreasing, with the highest weight of 30.52 g in T_6 - combination (soil) followed by 27.35 g in T_7 - $CuSO_4$ (foliar) as against 10.35 g of absolute control.

4.3.3 Dry matter accumulation in fruiting parts

Data on dry weight of fruiting parts per plant recorded at 75, 105 and 135 DAS are presented in Table-11 and Fig.7.

Dry matter accumulation of fruiting parts per plant differed significantly due to soil and foliar application of micronutrients at all the stages. There was increasing trend of dry weight of fruiting parts per plant from 75 to 135 DAS.

At 75 DAS, dry weight of fruiting parts differed significantly among various treatments. The highest dry weight of fruiting parts per plant was recorded in T_2, T_6 and T_{12}.

Table-10. Oven dried leaf dry matter (g) per plant at different growth stages of cotton as influenced by soil and foliar application of micronutrients under rainfed conditions

Treatments	45 DAS	75 DAS	105 DAS	135 DAS
T_1 - $CuSO_4$, 20 kg/ha (soil application)	5.75	16.83	34.38	24.18
T_2 - $MnSO_4$, 20 kg/ha (soil application)	7.15	16.50	28.50	22.28
T_3 - $FeSO_4$, 20 kg/ha (soil application)	6.66	18.08	27.15	23.05
T_4 - $ZnSO_4$, 20 kg/ha (soil application)	6.83	14.33	27.50	17.65
T_5 - Borax, 10 kg/ha (soil application)	5.50	20.83	24.65	24.25
T_6 - Combination of all five elements (soil application)	6.66	19.75	30.15	30.52
T_7 - $CuSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	6.00	15.83	32.00	27.35
T_8 - $MnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	7.33	17.50	33.15	20.55
T_9 - $FeSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	5.91	17.41	29.15	23.10
T_{10} - $ZnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	6.75	16.75	37.50	24.20
T_{11} - Borax, 2.5kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	6.16	16.58	32.35	19.75
T_{12} - Combination of all five elements (foliar spray at 60 & 90 DAS) in 2 equal splits	6.00	18.00	42.85	16.70
T_{13} - Water spray, control	5.50	10.66	20.85	12.50
T_{14} - Absolute control	5.50	10.11	23.00	10.35
S.Em. ±	0.45	1.20	3.50	2.20
C.D. at 5%	N.S.	3.60	10.38	6.30

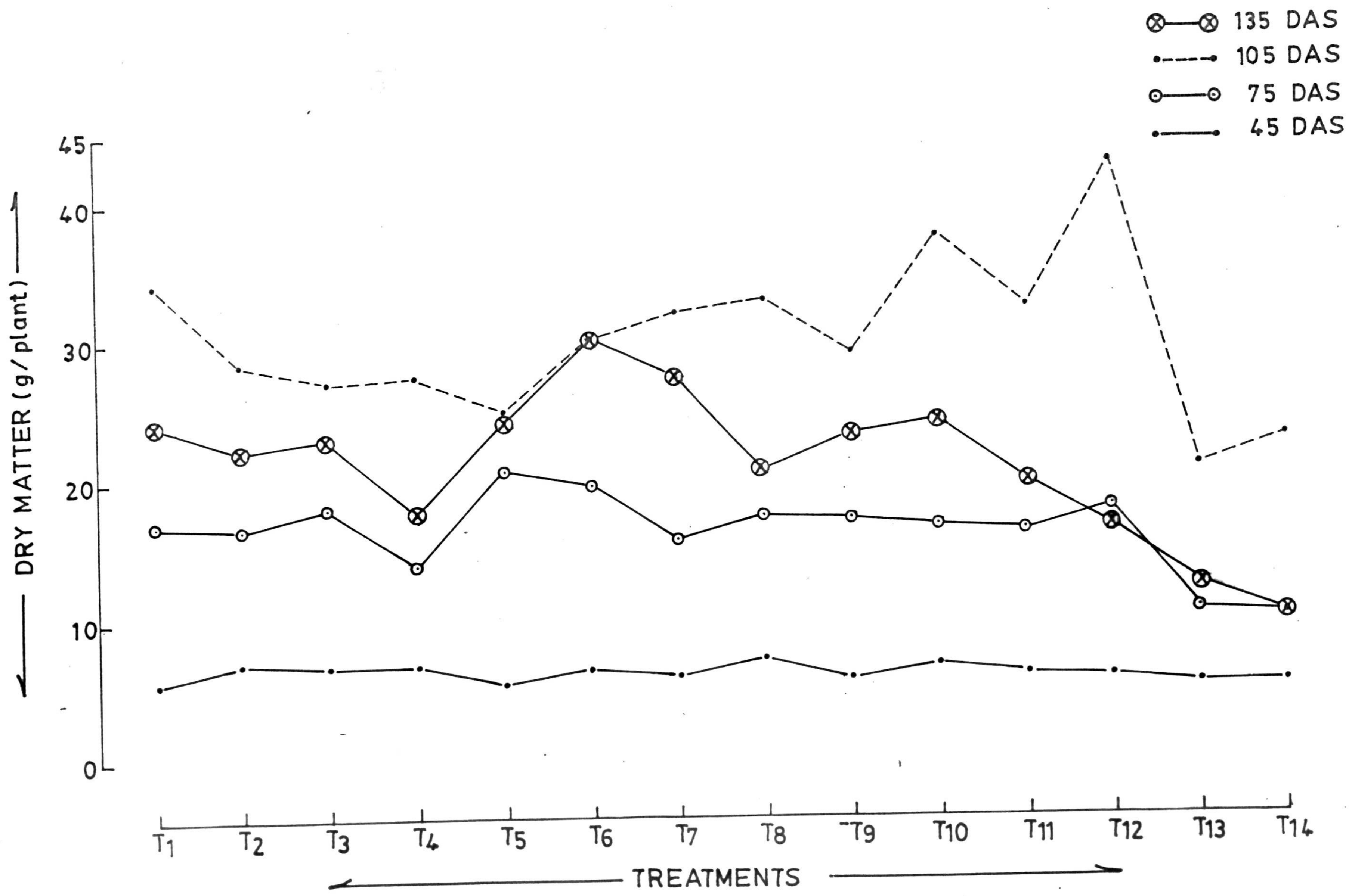

FIG: 6 - OVEN DRY WEIGHT OF LEAVES (g/plant) AT DIFFERENT GROWTH STAGES AS INFLUENCED BY SOIL AND FOLIAR APPLICATION OF MICRONUTRIENTS.

(1.25 g each).

At 105 DAS, combination of micronutrients applied through soil (12.75 g), foliar application of $CuSO_4$ (12.15 g) combination foliar (12.00 g), soil application of $CuSO_4$ (11.85 g), $FeSO_4$ (foliar) (11.80 g) and $ZnSO_4$ foliar (10.30 g) were significantly superior to water spray (5.85 g) and absolute control (3.80 g).

At 135 DAS, highest dry matter accumulation in fruiting parts was recorded in soil application of $ZnSO_4$ (65.30 g) followed by soil application of $MnSO_4$ (56.30 g) and foliar application of $CuSO_4$ (52.80 g). These recorded significant increase over control (16.30 g) but were among themselves on par with one another and so also T_9 and T_{12} increased the dry matter accumulation in fruiting parts, significantly.

4.3.4 Total dry matter production per plant

Data on the total dry matter production per plant in the above-ground plant parts at 45, 75, 105 and 135 DAS, are given in Table-12 and Fig.8.

At 45 DAS, there was no significant difference in total dry matter production either due to soil or foliar application of micronutrients.

At 75 DAS, the total dry matter increased significantly over control. Highest dry matter production was recorded in soil application of borax (47.58 g) followed by combination of micronutrients through soil (43.00 g), $CuSO_4$ (soil) (39.66 g) and $MnSO_4$ (soil) (38.58 g).

Table-11. Oven dried fruiting parts (g) per plant at 75, 105 and 135 DAS of JK-276-4 cotton as influenced by soil and foliar application of micronutrients under rainfed conditions

Treatments	75 DAS	105 DAS	135 DAS
T_1 - $CuSO_4$, 20 kg/ha (soil application)	0.66	11.85	34.30
T_2 - $MnSO_4$, 20 kg/ha (soil application)	1.25	9.15	56.30
T_3 - $FeSO_4$, 20 kg/ha (soil application)	0.62	9.65	39.75
T_4 - $ZnSO_4$, 20 kg/ha (soil application)	0.75	9.75	65.30
T_5 - Borax, 10 kg/ha (soil application)	1.16	8.60	28.25
T_6 - Combination of all five elements (soil application)	1.25	12.75	37.50
T_7 - $CuSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	0.66	12.15	52.80
T_8 - $MnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	0.79	7.85	38.90
T_9 - $FeSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	1.00	11.80	42.00
T_{10} - $ZnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	1.08	10.30	51.75
T_{11} - Borax, 2.5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	0.58	7.15	34.65
T_{12} - Combination of all five elements (foliar spray at 60 & 90 DAS) in 2 equal splits	1.25	12.00	45.60
T_{13} - Water spray control	0.54	5.85	21.00
T_{14} - Absolute control	0.50	3.80	16.30
S.Em. ±	0.20	1.40	6.80
C.D. at 5%	0.51	4.20	19.65

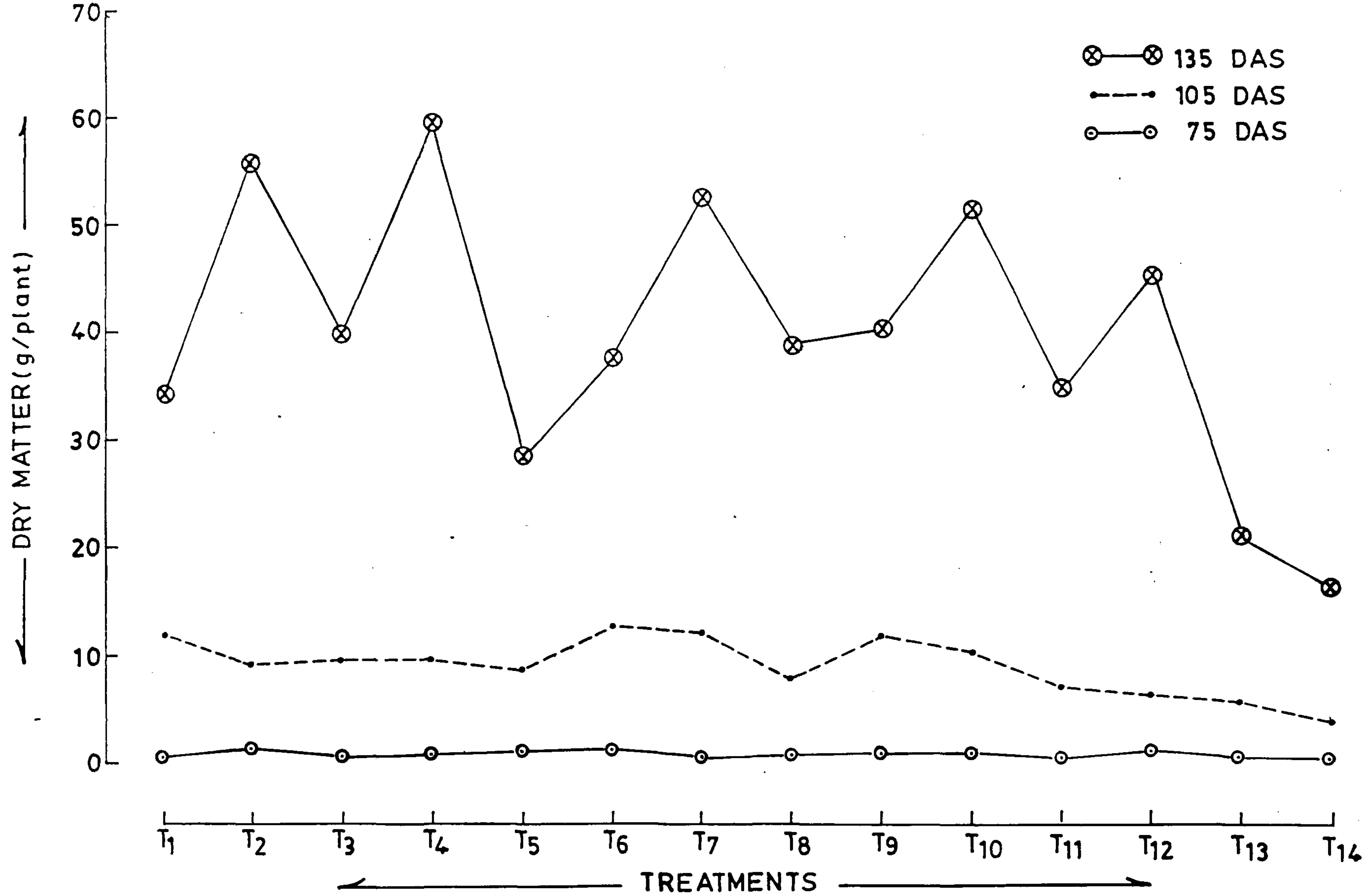

FIG:7-OVEN DRY WEIGHT OF FRUITING PARTS (g/plant) AT DIFFERENT GROWTH STAGES AS INFLUENCED BY SOIL AND FOLIAR APPLICATION OF MICRONUTRIENTS.

At 105 DAS, significantly higher total dry matter production was recorded in all the treatments except T_{13}. Soil application of $CuSO_4$ (105.95 g) and $CuSO_4$ (foliar) (102.15 g) and combination through soil (92.40 g) were significantly superior over water spray control (51.80 g), but were on par with one another among themselves.

At 135 DAS, the total dry matter production differed significantly among the various treatments. Treatments T_{10}, T_4, T_2 and T_7 were found significant over water spray and absolute control, but they themselves were on par with one another. Highest total dry matter per plant was recorded in $CuSO_4$ (foliar)(150.15 g) when compared to 54.05 of absolute control. Soil application was better for $MnSO_4$ and $ZnSO_4$ whereas foliar application was better for $CuSO_4$.

4.4 Yield components and yield

4.4.1 Number of squares per plant

Data on the number of squares per plant recorded at 75, 105 and 135 DAS are presented in Table-13.

Number of squares differed significantly among the treatments at all the three stages of crop growth. Number of squares reached the peak at 105 DAS and square formation was almost negligible later at 135 DAS.

Significant differences among the treatments were observed at 75, 105 and 135 DAS. At 75 DAS, significantly

Table-12. Total dry matter production (g/plant) at different growth stages of JK-276-4 cotton for soil and foliar application of micronutrients

Treatments	45 DAS	75 DAS	105 DAS	135 DAS
T_1 - $CuSO_4$, 20 kg/ha (soil application)	7.50	39.66	105.45	115.78
T_2 - $MnSO_4$, 20 kg/ha (soil application)	9.75	38.58	82.81	145.93
T_3 - $FeSO_4$, 20 kg/ha (soil application)	9.00	37.54	84.40	123.80
T_4 - $ZnSO_4$, 20 kg/ha (soil application)	8.91	32.91	70.95	145.45
T_5 - Borax, 10 kg/ha (soil application)	8.08	47.58	91.60	96.25
T_6 - Combination of allfive elements (soil application)	9.00	43.00	92.40	126.02
T_7 - $CuSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	8.16	36.16	102.15	150.15
T_8 - $MnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	9.90	36.79	92.25	110.85
T_9 - $FeSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	8.08	35.08	91.15	130.85
T_{10}- $ZnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	9.00	37.50	89.00	134.95
T_{11}- Borax,2.5kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	8.50	35.50	81.00	106.75
T_{12}- Combination of all five elements (foliar spray at 60 & 90 DAS) in 2 equal splits	8.15	37.50	98.95	119.60
T_{13}- Water spray, control	7.08	22.62	51.80	67.90
T_{14}- Absolute control	7.11	20.42	54.30	54.05
S.Em. ±	0.83	2.62	8.92	11.67
C.D. at 5%	N.S.	7.61	24.58	34.32

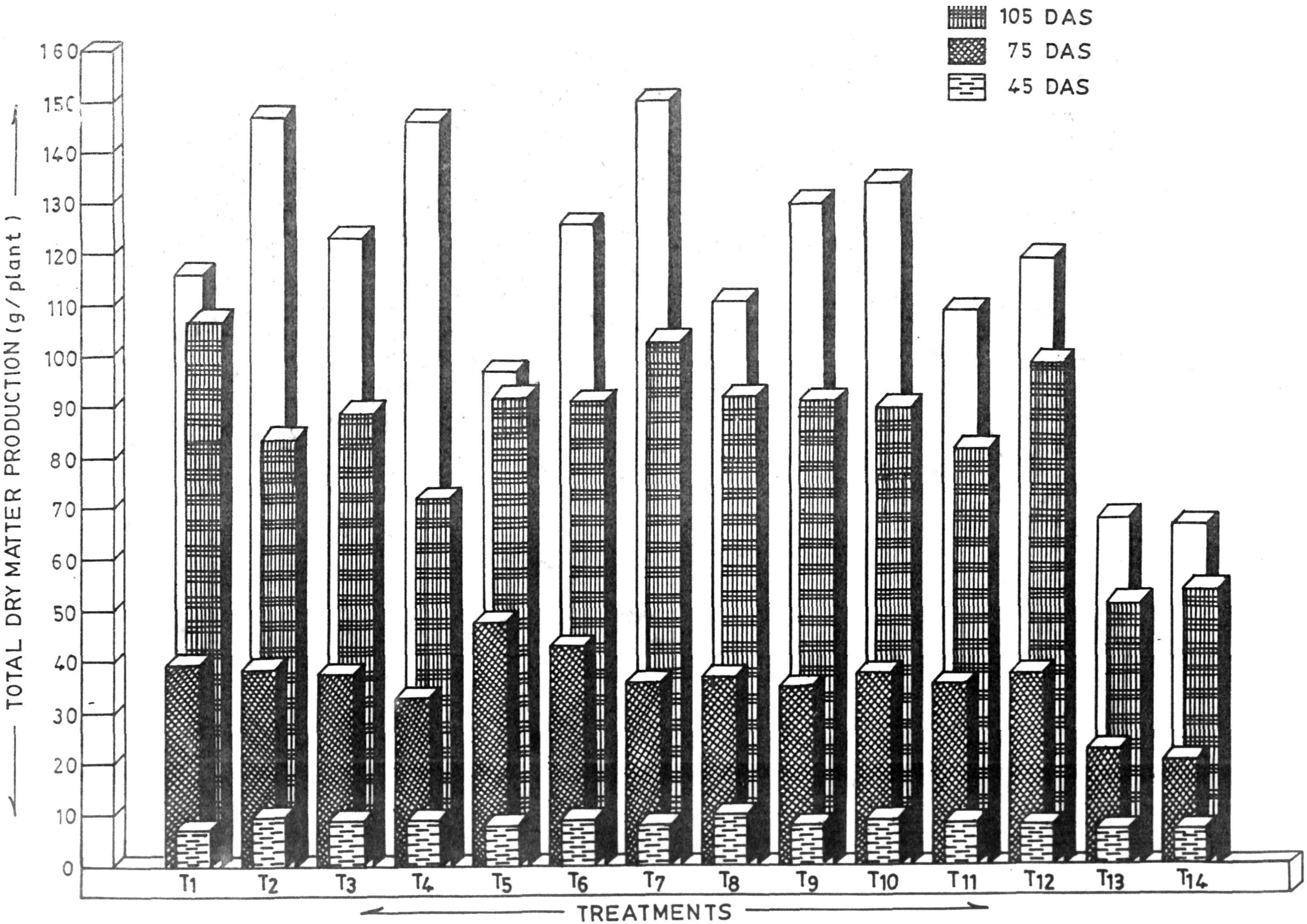

FIG:8-TOTAL DRY MATTER PRODUCTION (g/plant) AT DIFFERENT GROWTH STAGES AS INFLUENCED BY SOIL AND FOLIAR APPLICATION OF MICRONUTRIENTS.

higher number of squares per plant was recorded in all the treatments except T_3, T_9, T_{10} and T_{13}, over control. Highest number of squares was recorded in T_2 (19.6) followed by T_8 (17.50) and T_6 (17.0) as against 8.0 of absolute control and 9.83 of water spray control. At 105 DAS, highest number of squares was recorded in T_6 - soil application of combination (36.83) followed by T_7 - foliar application of $CuSO_4$ (33.16) and T_1 - soil application of $CuSO_4$ (33.0) as against 10.66 of control.

At 135 DAS, significant differences among the treatments were observed. T_1 - $CuSO_4$ (soil) recorded the highest of 3.00 squares/plant followed by T_8 - MnO_4 (foliar) with 2.83. Lowest number of squares per plant was recorded in T_2 and T_{12} (0.5 each) as against 2.16 of control.

4.4.2 <u>Number of green bolls per plant</u>

Data on the number of green bolls per plant recorded at different growth stages have been presented in Table-13.

Significant differences were observed due to soil and foliar application of micronutrients regarding number of green bolls per plant at 105 and 135 DAS.

At 105 DAS, highest number of green bolls per plant was recorded in soil application of $FeSO_4$ (17) followed by foliar application of $FeSO_4$ (15.66), combination of soil application (T_6) (14.33), foliar application of $CuSO_4$ (13.0) and foliar application of combination (12.33) when compared to absolute control (5.5).

Table-13. Production trend of number of squares and green bolls per plant at different growth stages as influenced by soil and foliar application of micronutrients under rainfed conditions cv. JK-276-4.

Treatments	75 DAS		105 DAS		135 DAS	
	Squares	Green bolls	Squares	Green bolls	Squares	Green bolls
T_1 - $CuSO_4$, 20 kg/ha (soil application)	14.50	-	33.00	13.33	3.00	20.16
T_2 - $MnSO_4$, 20 kg/ha (soil application)	19.60	-	22.50	8.83	0.50	20.00
T_3 - $FeSO_4$, 20 kg/ha (soil application)	9.00	-	24.00	17.00	0.83	24.83
T_4 - $ZnSO_4$, 20 kg/ha (soil application)	14.83	-	22.00	10.00	0.83	20.83
T_5 - Borax, 10 kg/ha (soil application)	19.33	-	27.66	8.50	1.83	16.50
T_6 - Combination of all five elements (soil application)	17.00	-	36.83	14.33	0.66	19.66
T_7 - $CuSO_4$, 5 kg/ha(foliar spray at 60 & 90 DAS) in 2 equal splits	14.66	-	33.16	13.00	1.16	20.50
T_8 - $MnSO_4$, 5 kg/ha(foliar spray at 60 & 90 DAS) in 2 equal splits	17.50	-	26.00	10.00	2.83	15.00
T_9 - $FeSO_4$, 5 kg/ha(foliar spray at 60 & 90 DAS) in 2 equal splits	10.66	-	29.50	15.66	1.33	15.50
T_{10}- $ZnSO_4$, 5 kg/ha(foliar spray at 60& 90 DAS) in 2 equal splits	10.83	-	26.00	10.00	1.00	19.01
T_{11}- Borax, 2.5kg/ha(foliar spray at 60 & 90 DAS) in 2 equal splits	11.83	-	20.66	10.50	1.50	14.50
T_{12}- Combination of all five elements(foliar spray at 60 & 90 DAS) in 2 equal splits	16.67	-	28.00	12.33	0.50	17.66
T_{13}- Water spray, control	9.83	-	13.16	6.50	0.66	12.00
T_{14}- Absolute control	8.00	-	10.66	5.50	2.16	9.50
S.Em. ±	1.29	-	2.70	2.50	0.29	1.01
C.D. at 5%	3.77	-	7.82	7.36	0.85	2.94

At 135 DAS, there was significant difference in the number of green bolls per plant of different treatments. T_3 - soil application of $FeSO_4$ recorded highest number of green bolls per plant (24.83) followed by T_4 - soil application of $ZnSO_4$ (20.83), T_7, foliar application of $CuSO_4$ (20.50) and T_1 - soil application of $CuSO_4$ (20.16) as against 9.50 of absolute control and 12.00 of water spray. In general, green bolls were higher in soil application than in foliar application of micronutrients. The increase in number of green bolls in different treatments over absolute control (9.50) varied from 2.50 to 15.33.

4.4.3 Number of harvested bolls per plant

Data on number of harvested bolls per plant are given in Table-14 and Fig.9.

Different treatments differed significantly with respect to number of harvested bolls per plant. Treatments T_2, T_1, T_5, T_4, T_{11}, T_{12}, T_{10}, T_8 and T_9 were found significant over control but they themselves were on par with one another.

4.4.4 Mean boll weight (g)

Data on mean boll weight recorded, are given in Table 14 and Fig.9.

There was nonsignificant difference among treatments as regards boll weight. However, numerically highest mean boll weight was recorded in soil application of borax (4.50 g) followed by T_7 - foliar application of $CuSO_4$ (4.47 g) T_4 - soil application of $ZnSO_4$ (4.23g) as compared to 388 g of water spray and 4.04 of absolute control.

4.4.5 Kapas yield per plant

Data on the kapas yield per plant as influenced by soil and foliar application of micronutrients are given in Table-14 and Fig.9.

Yield per plant was significantly higher in case of foliar application of $FeSO_4$, $ZnSO_4$, $MnSO_4$, $CuSO_4$ and combination when compared to soil applications of the same elements. The increase over control (26.93 g) varied from 3.40 g in T_{13} - water spray to 22.4 g in T_9 - foliar application of $FeSO_4$. Foliar application of $FeSO_4$ recorded the highest yield per plant (49.33 g) followed by T_{10} - foliar application of $ZnSO_4$ (48.87 g), T_8 - foliar application of $MnSO_4$ (47.93 g), T_7 - foliar application of $CuSO_4$ (47.13 g) and T_5 - soil application of borax (45.53 g) as against 26.93 g of absolute control. All these treatments were significantly superior to control. The remaining treatments also increased the yield per plant but not significantly. There was not much difference in the yield per plant between soil and foliar application of micronutrients.

4.4.6 Yield per hectare

Data on the yield of seed cotton (kg/ha) as influenced by soil and foliar application of micronutrients are presented in Table-14 and Fig.9.

All the treatments increased the yield of seed cotton significantly over absolute control as well as water spray control. But they themselves were on par with one another.

. $FeSO_4$ (foliar application) gave the highest yield of 2446 kg/ha followd very closely by $ZnSO_4$ (foliar application) with 2405 kg/ha. Next in order were : $CuSO_4$ (foliar) (2337 kg/ha) borax (soil) (2291 kg/ha) and combination (foliar) (2241 kg/ha) as against 1544 kg/ha of control/water spray. The increase in yield of these treatments over control works out to 902, 861, 793, 747 and 697 kg/ha or 58 56. 51 , 48 and 45 per cent, respectively. The increase in yield of $MnSO_4$ (soil) (2144 kg/ha) and $FeSO_4$ (soil) (2164 kg/ha) (39 and 40%) was also significant over control. Combination (soil) (2066 kg/ha), $MnSO_4$ (foliar) (2003 kg/ha) and borax(foliar) (2009 kg/ha) also gave 464 to 522 kg/ha increased yield over control the increases (522, 459 and 465 kg/ha or 34, 30 and 30.0% respectively) were significant.

Thus, it is seen that application of micronutrients gave significantly and appreciably higheryields over control. While soil application was better in case of Mn, B and foliar application was good for Fe, Zn, Cu and Combination.

Table-14. Number of harvested bolls per plant, mean boll weight (g), kapas yield (g/plant and kg/ha) as influenced by soil and foliar application of micronutrients under rainfed conditions

Treatments	Harvested bolls/plant	Mean boll weight (g)	Yield/ plant (g)	Yield/ (kg/ha)	Increase in yield over control (Kg/ha)
T_1 - $CuSO_4$, 20 kg/ha (soil application)	9.86	4.04	39.93	2189	645 (42%)
T_2 - $MnSO_4$, 20 kg/ha (soil application)	9.33	4.15	38.80	2144	600 (39%)
T_3 - $FeSO_4$, 20 kg/ha (soil application)	8.73	3.81	33.36	2164	620 (40%)
T_4 - $ZnSO_4$, 20 kg/ha) (soil application)	10.20	4.23	43.14	2188	644 (42%)
T_5 - Borax, 10 kg/ha (soil application)	10.00	4.50	45.53	2291	747 (48%)
T_6 - Combination of all five elements (soil application)	8.30	3.96	32.93	2066	522 (34%)
T_7 - $CuSO_4$, 5 kg/ha (foliar application at 60 & 90 DAS)in 2 equal splits	10.53	4.47	47.13	2337	793 (51%)
T_8 - $MnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	12.33	3.89	47.93	2003	459 (29%)
T_9 - $FeSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	12.33	4.11	49.33	2446	902 (58%)
T_{10}- $ZnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	11.80	4.14	48.87	2405	861 (56%)
T_{11}- Borax,2.5 kg/ha(foliar spray at 60 & 90 DAS) in 2 equal splits	10.20	4.00	40.87	2009	465 (30%)
T_{12}- Combination of all five elements (foliar spray at 60 & 90 DAS) in 2 equal splits	10.40	3.73	38.87	2241	697 (45%)
T_{13}- Water spray control	7.80	3.88	30.33	1546	002 (0.16%)
T_{14}- Absolute control	6.50	4.04	26.93	1544	-

S.Em. ±	1.14	0.523	1.32	152
C.D. at 5%	3.32	N.S.	3.82	446

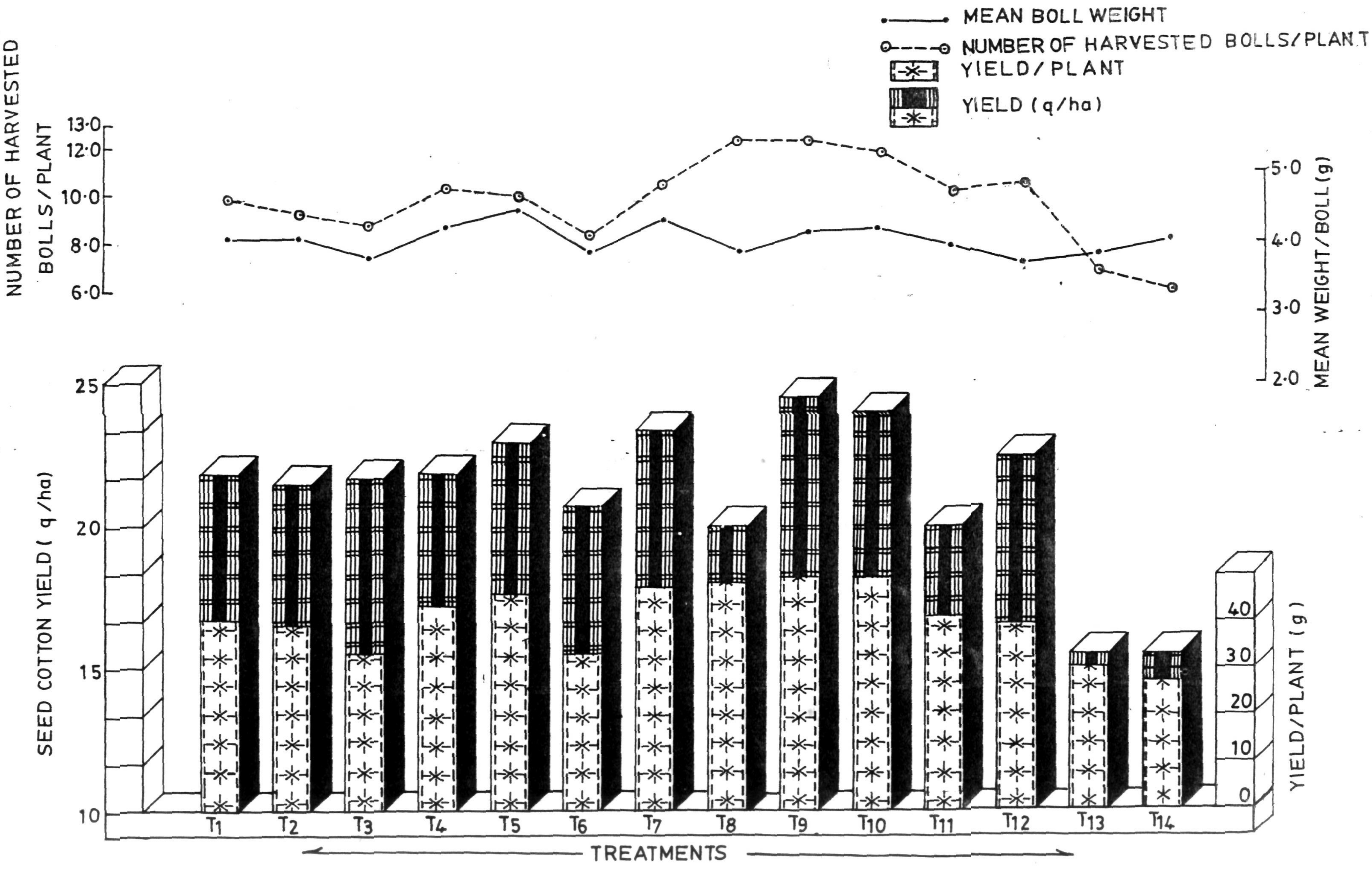

FIG:9-KAPAS YIELD (g/plant and kg/ha), MEAN BOLL WEIGHT (g) AND NUMBER OF HARVESTED BOLLS/PLANT AS INFLUENCED BY SOIL AND FOLIAR APPLICATION OF MICRONUTRIENTS.

4.4.7 Number of seeds per boll

Data on number of seeds per boll as influenced by soil and foliar application of micronutrients are presented in Table-15.

Significant differences were observed among the treatments in respect of number of seeds per boll. Treatments T_{12}, T_7, T_6, T_4, T_2, T_8, T_3 and T_9 were found significant over absolute control as well as water spray control, but they themselves showed on par effect with one another. Highest number of seeds per boll was recorded in foliar application of $FeSO_4$ (30.06) and soil application of $FeSO_4$ (30.00) as compared to 26.63 of absolute control.

4.4.8 Seed index

Data in respect of seed index as influenced by soil and foliar application of micronutrients are given in Table-15.

Statistically non-significant differences in seed index among the treatments was found. However, foliar application of $MnSO_4$ (T_8) recorded the highest seed index of 9.13 g followed by foliar application of $CuSO_4$ (9.06 g), $FeSO_4$-foliar (8.93g), borax -(soil) (8.90 g), $ZnSO_4$ - foliar (8.83 g) and borax-foliar (8.83 g) when compared to control (8.30 g).

4.4.9 Ginning per cent

Data on ginning per cent as influenced by soil and foliar application of micronutrients are presented i[illegible]as.

[illegible]ant differences in ginning per cent were observed [illegible] the different soil and foliar treatments.

Treatments T_6, T_2, T_{11} and T_3 were found significant over control and themselves showed on par effect with one another. T_6 - soil application of combinaton recorded the highest ginning per cent (43.20) followed by T_2-soil application of $MnSO_4$ (41.10), T_{11} - foliar application of borax and T_3 - soil application of $FeSO_4$ (40.01) as against 37.71 per cent of absolute control. The increase over control (37.71) varied from 0.05 in T_7 to 5.49 per cent in T_6. Both soil and foliar applications were better in case of $FeSO_4$ (40.01 and 40.16). T_4, T_8, T_9 and T_{12} were also significant.

4.4.10 Lint index

Data on lint index as affected by soil and foliar application of micronutrients are presented in Table-15.

Significant differences among the treatments were recorded in respect of lint index. Treatments T_6 and T_8 were found significant over water spray or absolute control. Highest lint index (6.39) was recorded in soil application of combination followed by foliar application of $MnSO_4$ (6.01) as against 5.16 of water spray and 5.48 of absolute control.

Table-15. Number of seeds per boll, seed index, ginning per cent and lint index of cotton (cv. Abadhita) as influenced by methods of micronutrient application

Treatments	No. of seeds/ boll	Seed index	Ginning per cent	Lint index
T_1 - $CuSO_4$, 20 kg/ha (soil application)	28.30	8.63	38.54	5.29
T_2 - $MnSO_4$, 20 kg/ha (soil application)	28.96	8.50	41.10	5.93
T_3 - $FeSO_4$, 20 kg/ha (soil application)	30.00	8.76	40.01	5.85
T_4 - $ZnSO_4$, 20 kg/ha (soil application)	28.40	8.73	39.70	5.76
T_5 - Borax, 10 kg/ha (soil application)	27.50	8.90	38.06	5.26
T_6 - Combination of allfive elements (soil application)	28.80	8.76	43.20	6.39
T_7 - $CuSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	28.86	9.06	37.76	5.50
T_8 - $MnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	29.30	9.13	39.73	6.01
T_9 - $FeSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	30.06	8.93	40.16	5.64
T_{10}- $ZnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	28.30	8.83	38.33	5.48
T_{11}- Borax, 2.5kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	28.60	8.83	40.38	5.94
T_{12}- Combination of all five elements (foliar spray at 60 & 90 DAYS) in 2 equal splits	28.63	8.70	38.79	5.28
T_{13}- Water spray, control	27.43	8.03	39.12	5.16
T_{14}- Absolute control	26.63	8.30	37.71	5.46
S.Em. ±	0.62	0.20	0.51	0.20
C.D. at 5%	1.81	N.S.	1.48	0.57

4.5 Fibre properties

4.5.1 Fibre length

Data on fibre length, as affected by soil and foliar application of micronutrients are presented in Table-16.

There was no significant difference in the fibre length of different treatments. However, T_6- soil application of combination recorded the highest fibre length (25.5 mm), followed by T_4 - soil application of $ZnSO_4$ (25.1 mm), T_1 - soil application of $CuSO_4$ (25.06 mm) as against control (24.30 mm).

4.5.2 Fibre uniformity ratio

Data on fibre uniformity ratio (%) are presented in Table-16.

Fibre uniformity ratio was not affected significantly either by soil or by foliar application of micronutrients. But, soil application of combination (T_6) and foliar application of $ZnSO_4$ (T_{10}) recorded higher per cent uniformity ratio (50%) whereas other treatments including control, showed slightly lower values.

4.5.3 Fibre fineness

Data on fibre fineness (10^{-6} g/inch) of different treatments are presented in Table-16.

Neither soil nor foliar application of micronutrients influenced fibre fineness significantly. However, soil application of $FeSO_4$, foliar application of $MnSO_4$ and foliar application of combination recorded higher but equal values of micronnaire (3.36) as against 3.06 of control.

4.5.4 Maturity coefficient

Data on maturity coefficient are given in Table-16.

Maturity coefficient of different treatments differed significantly over control. Except T_9 and T_{13}, all other treatments were found on par with one another. However, highest maturity coefficient was recorded in T_9-foliar application of $FeSO_4$ (0.69), followed by T_3 - soil application of $FeSO_4$ (0.68), and T_8 - foliar application of $MnSO_4$ (0.66) as against 0.60 of absolute control. Both soil and foliar applications were found better in case of $FeSO_4$ and $MnSO_4$.

4.5.5 Bundle strength

Data on bundle strength (g/tex) are presented in Table-16.

Bundle strength was affected significantly due to soil and foliar application of micronutrients. Highest bundle strength of 43.96 was recorded in foliar application of $MnSO_4$ followed by soil application of $MnSO_4$ (42.73) as against 38.76 of control. Except T_4, T_6 and T_{12}, all the remaining treatments were significantly superior over absolute control.

Table-16. Fibre properties of cottn cv. Abadhita as influenced by soil and foliar application of micronutrients under rainfed conditions

Treatments	Fibre length (mm)	Uniformity ratio (%)	Fineness (micronaire)	Maturity coefficient	Bundle strength
T_1 - $CuSO_4$, 20 kg/ha (soil application)	25.06	48.33	3.22	0.64	42.10
T_2 - $MnSO_4$, 20 kg/ha (soil application)	24.90	49.00	3.26	0.65	42.73
T_3 - $FeSO_4$, 20 kg/ha (soil application)	24.50	49.66	3.36	0.68	42.13
T_4 - $ZnSO_4$, 20 kg/ha (soil application)	25.10	49.33	3.20	0.64	40.86
T_5 - Borax, 10 kg/ha (soil application)	24.80	49.66	3.16	0.64	41.33
T_6 - Combination of all five elements (soil application)	25.50	50.00	3.30	0.65	40.63
T_7 - $CuSO_4$, 5 kg/ha(foliar spray at 60 & 90 DAS) in 2 equal splits	24.90	49.33	3.30	0.65	41.43
T_8 - $MnSO_4$, 5 kg/ha(foliar spray at 60&90 DAS) in 2 equal splits	24.53	49.66	3.36	0.66	43.96
T_9 - $FeSO_4$, 5 kg/ha(foliar spray at 60&90 DAS) in 2 equal splits	25.36	49.33	3.20	0.69	41.30
T_{10}- $ZnSO_4$, 5 kg/ha(foliar spray at 60&90 DAS) in 2 equal splits	24.73	50.00	3.20	0.65	41.80
T_{11}- Borax, 2.5kg/ha(foliar spray at 60&90DAS) in 2 equal splits	24.90	49.00	3.26	0.65	41.03
T_{12}- Combination of all 5 elements(foliar application at 60&90 DAS)in 2 equal splits	24.60	49.33	3.36	0.65	40.90
T_{13}- Water spray control	24.73	49.33	3.16	0.62	39.80
T_{14}- Absolute control	24.30	48.00	3.06	0.60	38.76
S.Em. ±	0.32	0.56	0.08	0.02	0.80
C.D. at 5%	N.S.	N.S.	N.S.	0.07	2.30

4.6 Nutrient uptake (kg/ha)

4.6.1 Nitrogen

Data on nitrogen uptake by the crop at 135 DAS are presented in Table-17.

There was significant difference in the nitrogen uptake of all the treatments. Treatments T_4, T_1, T_7, T_3 and T_9 were significant over control and they themselves on par with one another. T_9 - foliar application of $FeSO_4$ recorded the highest uptake (134.16 kg/ha) followed by T_3 - soil application of $FeSO_4$ (132.03 kg/ha), T_1 - soil application of $CuSO_4$ (130.33 kg/ha) and T_4- soil application of $ZnSO_4$ (129.33 kg/ha) as against 104.36 kg/ha of absolute control. Soil and foliar application of $CuSO_4$, recorded almost equal uptake of nitrogen (130.33 and 130.41 kg/ha). While soil application was better in treatments T_1 and T_3, foliar application was better for T_7 and T_9.

4.6.2 Phosphorus

Data on phosphorous uptake by cotton crop at 135 DAS are given in Table-17.

There was significant difference in phosphorous uptake among the various treatments. Treatments T_6, T_7, T_9 and T_{12} were found significant over control but on par with one another.

T_9 - foliar application of $FeSO_4$, 5 kg/ha sprayed in two equal split doses at 60 and 90 DAS recorded the highest uptake of P_2O_5 (12.60 kg/ha) followed by T_7 - foliar application of $CuSO_4$ (11.63 kg/ha), T_6 - combination of soil application (11.20 kg/ha) and T_{12} - foliar application of combination (10.80 kg/ha) as against 7.90 kg/ha of absolute control. However, the uptake of P_2O_5 was low with the soil and foliar application of $MnSO_4$, $ZnSO_4$ and borax. Both soil and foliar application of $FeSO_4$ were better for P_2O_5 uptake.

4.6.3 Potassium

Data on potassium uptake by the crop at 135 DAS, are presented in Table-17.

Significant differences among various treatments for potassium uptake were bserved. $FeSO_4$ foliar spray 5 kg/ha (T_9) registered the highest uptake of potassium (156.5 kg/ha) against 105.67 kg/ha of absolute control. Besides, this treatment was significant from other treatments. $MnSO_4$, $FeSO_4$ and $ZnSO_4$ were better for both soil and foliar application.

T_1, T_7, T_8, T_6, T_2, T_3 and T_4 were found on par with one another but significant over control. Absolute control and water spray control recorded the lowest uptake of 105.67 and 11.60 kg/ha of K_2O, respectively.

Table-17. NPK uptake (kg/ha) as influenced by soil and foliar application of micronutrients at 135 DAS to cotton

Treatments	Uptake (kg/ha)		
	N	P_2O_5	K_2O
T_1 - $CuSO_4$, 20 kg/ha (soil application)	130.33	9.96	141.20
T_2 - $MnSO_4$, 20 kg/ha (soil application)	122.80	9.46	146.33
T_3 - $FeSO_4$, 20 kg/ha (soil application)	132.03	10.24	146.33
T_4 - $ZnSO_4$, 20 kg/ha (soil application)	129.33	9.49	146.67
T_5 - Borax, 10 kg/ha (soil application)	118.50	9.76	118.77
T_6 - Combination of all five elements (soil application)	120.00	11.20	119.17
T_7 - $CuSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	130.41	11.63	142.83
T_8 - $MnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	128.50	8.80	142.30
T_9 - $FeSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	134.16	12.60	156.50
T_{10}- $ZnSO_4$, 5 kg/ha (foliar spray at 60 & 90 DAS) in 2 equal splits	123.43	9.13	142.23
T_{11}- Borax, 2.5 kg/ha(foliar spray at 60 & 90 DAS) in 2 equal splits	118.90	8.80	115.17
T_{12}- Combination of all five elements (foliar spray at 60 & 90 DAS) in 2 equal splits	121.66	10.80	120.83
T_{13}- Water spray control	108.23	8.81	110.60
T_{14}- Absolute control	104.36	7.90	105.67
S.Em. ±	2.43	0.72	2.01
C.D. at 5%	7.03	2.10	5.82

CHAPTER - V

DISCUSSION

V. DISCUSSION

The results obtained from the experiment conducted at Agricultural Research Station, Dharwad farm, during the year 1991-92 to study the response of cotton cv. Abadhita (*Gossypium hirsutum* L.) to soil and foliar application of micronutrients under rainfed conditions are discussed below.

The meteorological data (Table-1) revealed that the seasonal conditions during the period of crop growth were normal. Rainfall during the year 1991-92 was 1190 mm i.e., (425 mm) 35.7 per cent more than the normal rainfall (765 mm) for the experimental station. On the other hand, the number of rainy days during the year were 83 against the normal of 97, i.e., less by 14 days. Rain was received in high intensity at times. The rainfall was particularly high during April, May and June and less during August and November. Apart from excessive rain, the weather was continuously cloudy for a period of about four months i.e., June to September. Sowing was done during the second week of July.

Apart from higher rainfall during 1991-92, less incidence of bollworm was noticed starting early in the season which however prevailed till the end of November and was controlled effectively by plant protection measures.

On the whole, it could be stated that higher rainfall of the year coupled with very less incidence of bollworm was helpful for the cotton crop. However, continuous cloudy weather for four months from June till September resulted in excessive vegetative growth of cotton crop and delayed reproductive phase.

5.1 Response of cotton to micronutrients

5.1.1. Growth Components

Significant differences in plant height of different treatments was observed at 45, 75 and 105 DAS but not at 135 DAS. Application of micronutrients through soil or foliar application did not increase the number of monopodial branches significantly. However, compared with control there was numerical increase in the number of monopodia per plant in case of different micronutrient treatments. Significant differences in number of sympodial branches was observed at 75 and 105 DAS, but not at 135 DAS. Number of leaves per plant differed significantly at all the stages of observation. Similar results were also reported by Sarour *et al.* (1988) and Patel and Patel (1949). Nonsignificant difference of sympodial branches per plant reported by Ahlawat (1974) and Asab and El-Halawamy (1989) also found that micronutrient application had no effect on number of nodes and sympodial branches per plant.

Significant increase in the plant height at early stages may be due to the effect of application of micro-nutrients through soil. The increased plant height particularly in case of boron (soil) is due to its requirement by the meristomatic regions of the plant. Berger (1949) has mentioned that boron is very important in cell division and forms an essential component of cell-wall. Similarly, Tsui (1948) has given convincing evidence on the important role of Zn in the production of growth promoting hormones and it is likely that the appreciable increase in growth might be due to this factor. Application of micronutrients through soil and foliar spray increased the uptake of N, P_2O_5 and K_2O significantly which in turn might have helped in the growth of cotton plant.

The differences in leaf area (dm^2) and LAI were not significant at 45 DAS, whereas the treatments differed significantly at 75, 105 and 135 DAS.

At 135 DAS, foliar application of $ZnSO_4$ (47.862 dm^2) and $FeSO_4$ (47.378 dm^2) recorded higher leaf area per plant than that of water spray control (31.424 dm^2) and absolute control (31.282 dm^2). Soil application of $CuSO_4$ and foliar application of $CuSO_4$, $MnSO_4$ and combination also recorded significantly higher leaf area than that of both water spray and absolute control. At 135 DAS, soil application of $FeSO_4$, $ZnSO_4$, borax and combination recorded significantly lower LAI. However, foliar application of micronutrients either alone or in combination recorded significantly higher LAI as compared to that of absolute control. Significant differences were observed for AGR between 45-75, 76-105, and 106-135 DAS periods. Relative growth rate of cotton was significantly higher at initial stage (45-75 DAS), whereas with increasing growth, there w s decreasing trend of RGR which therefore showed non-significant differences at later stages (76-135 DAS).

In general, foliar application of $ZnSO_4$, combination (soil), soil application of $ZnSO_4$ and $CuSO_4$ (soil) were found better for increasing LA, LAI, AGR and RGR respectively. Such results were also reported by Sarour et al. (1988) that foliar application of 4% urea either alone or in combination with mixture of micronutrients gave the highest dry matter and largest leaf area per plant and LAI. This might be due to higher uptake of NPK by the cotton plant in Zn applied as both soil and foliar, combination (soil) and $CuSO_4$ (soil) treatments. Besides this, Zn is known to play a definite role in the synthesis of tryptophane - a precursor to indole acetic acid, a growth hormone in plants. Tsui (1948)'s work has provided convincing proof, regarding the important role played by Zn in the production of growth promoting hormones and the appreciable increase in the physiological parameters by Zn might be due to these effects.

With respect to stem dry matter accumulation, significant differences at 45,75, and 135 DAS were recorded but not at 135 DAS.

At 105 DAS, highest stem dry matter was recorded in soil application of $CuSO_4$ (59.75 g) followed by foliar application of $CuSO_4$ (58.40 g), soil application of borax (58.0 g) and $FeSO_4$ (51.6 g). At 135 DAS, stem dry matter showed non-significant differences. However, soil applied micronutrients increased the stem dry matter accumulation numerically compared to foliar applied treatments including control. Leaf dry matter weight at 45 DAS, showed statistically non-significant difference, whereas at 75, 105 and 135 DAS, differed significantly. At 75 DAS, dry matter in stem was highest in T_5 - soil application of borax followed by T_6 - combination (soil), T_3 - $FeSO_4$ (soil) and T_8 - $MnSO_4$ (foliar). There was significantly highest leaf dry weight at 105 DAS, thereafter decreasing due to defoliation effect at later stages. Dry matter production in fruiting parts differed significantly due to soil and foliar application of micronutrients at 75, 105 and 135 DAS stages. Increasing trend of dry weight of fruiting parts was observed due to continuous production of squares, flowers and bolls. As regards total dry matter (TDM) except at 45 DAS, there was statistically significant difference in total dry matter production both due to soil and foliar application of micronutrients. Soil application of $CuSO_4$ $ZnSO_4$ (soil), $MnSO_4$ (soil), $ZnSO_4$(foliar), $FeSO_4$ (foliar) and combination (soil) were more effective in increasing TDM accumulation per plant. Soil application of combination recorded 126.02 g of TDM per plant when compared with 119.6 g of foliar application of combination as against 67.9 g of water spray and 54.05 g of control.

On the whole, $CuSO_4$ (soil), combination (soil), $ZnSO_4$ (soil) and $CuSO_4$ (foliar) were found better for increasing dry weights of stem, leaf, fruiting parts and total dry matter production per plant, respectively. Such results were also obtained by Sarour et al. (1988) that foliar application of mixture of micronutrients gave the highest dry matter. The reason could be attributed that dry matter increases as the stage advances due to increase in LA, LAI and AGR due to the application of micronutrients. $CuSO_4$ acts as catalyst in oxidation and reduction reactions. It is also believed that Cu may function in photosynthesis, thereby increasing the number of leaves per plant, stem and fruiting parts which resulted in greater production of total dry matter. Boron is also believed to facilitate translocation of sugars and carbohydrates in plant and is required by the meristematic regions of the plant (Varma, 1973).

5.1.2 Yield components and yield

Significant differences among the treatments were observed at 75, 105 and 135 DAS as regards to number of squares per plant. Highest number of squares per plant was recorded in soil application of combination (36.83) followed by foliar spray of $CuSO_4$ (33.16). Soil application of $CuSO_4$, $FeSO_4$, $ZnSO_4$ and $MnSO_4$ recorded 33.0, 24.0, 22.5 and 22.0 number of squares per plant respectively when compared to foliar application of the same elements which recorded 33.1, 29.5, 26.0 and 26.0 number of squares per plant, respectively.

Significantly higher number of green bolls per plant was recorded in soil application of $FeSO_4$ (24.83), followed by soil application of $ZnSO_4$ (20.83), $CuSO_4$ (20.16) and $MnSO_4$ (20.0) against 9.50 of absolute control at final stage. Significantly higher number of harvested bolls per plant was recorded in foliar application of $MnSO_4$ (T_8), $FeSO_4$ (T_9) and $ZnSO_4$ (T_{10}). Mean boll weight was found nonsignificant. However, numerically highest mean boll weight (4.5 g) was recorded in soil application of borax, where as soil application of $FeSO_4$, combination (T_6), $MnSO_4$ (foliar), combination (foliar) and water spray control (3.81, 3.96, 3.89, 3.73 and 3.88 respectively) recorded almost equal mean boll weight. Significant difference was observed in respect of yield per plant. Highest yield per plant was recorded in $FeSO_4$ (foliar) (49.33 g) followed by $ZnSO_4$ (foliar) (48.87 g) over 26.93 g of control.

At 135 DAS the number of squares per plant were negligible and highest squares were observed in soil application of $CuSO_4$ and highest number of green bolls per plant was observed in $FeSO_4$ (soil). $MnSO_4$ (foliar), $FeSO_4$ (foliar), borax (soil) and $FeSO_4$ (foliar) were found beneficial to increase the number of harvested bolls per plant, boll weight and yield per plant respectively. Such findings were also reported by Sarour <u>et al.</u> (1988) that all the foliage sprayed micronutrients increased the number of squares per plant significantly and it decreased the shedding as compared to control, which is suppoted by the findings of Srivastava and Singh (1988).

El-Gharieb et al. (1986) and Azab and El-Halawamy (1988) reported significant increase of number of bolls per plant, boll weight and yield per plant whereas Ahlawat (1974) and SarOmr/et al. (1988) reported nonsignificant effect of number of green bolls per plant. This positive beneficial effect on yield parameters can be attributed to higher number of total bolls retained and harvested bolls per plant and increased LA, LAI and increased transport of photosynthates from source to sink followed by higher absorption and better utilization of micronutrients, thus influencing boll weight and number of bolls per plant. Fe is believed to be essential for the synthesis of chlorophyll and biological nitrogen fixation and primary photochemical reaction in photosynthesis (Varma, 1973). This it could be reasoned out that foliar application of Fe was better for increasing the number of harvested bolls per plant and mean boll weight and thereby increased the yield per plant. Mn also plays some role in the synthesis of chlorophyll and in the transfer of electrons from water to photoxidised chlorophyll in photosynthesis. Hence, it might have been responsible to increase the number of harvested bolls and yield per plant.

$FeSO_4$ applied through foliage recorded significantly highest seed cotton yield (24 46 kg/ha) followed by foliar application of $ZnSO_4$ (2405 kg/ha), $CuSO_4$ (2337 kg/ha)and combination spray (2241 kg/ha) when compared with control (1544 kg/ha). Soil application of combination (T_6) recorded lower yield of seed cotton (2066 kg/ha) when compared with foliar spray of combination (2241 kg/ha). Asab and El-Halawany (1989), Sharma and Gupta (1989) also reported that soil containing 0.48 ppm available Zn, responded to 25.50 kg/ha $ZnSO_4$ applied, broadcast or drilled or a foliar spray of 0.5% $ZnSO_4$ increasing the seed cotton yield by 1.8-15, 2.5-7.5 and 6.8 per cent, respectively. Kamalanathan et al. (1966) reported that $FeSO_4$ (soil and foliar) tended to increase the yield of seed cotton at Coimbatore. These findings are also authenticated by the findings of El-Gharieb et al. (1986).

Soil application of micronutrients also performed better for increasing the seed cotton yield when compared to controls. This is supported by Nageshwara Rao (1977) who found that soil application of Mg, B and Zn increased the seed cotton yield by 16, 26 and 21 per cent, respectively and by Dastur and Singh (1953), Anderson and Fured (1968), Varma et al. (1984), Srivastava and Singh (1988), Sharma et al.(1988) and Kumar and Gupta (1989).

Highest increase in yield of seed cotton (902 kg/ha) (58%) over absolute control was noticed in foliar application of $FeSO_4$, followed by foliar application of $ZnSO_4$ (861 kg/ha - 56%), $CuSO_4$ (793 kg/ha - 51%) and combination-foliar (697 kg/ha-45%). These results agree with the findings of Nageshwara Rao (1977) who found increased seed cotton yield in foliar sprays of Mg (33%), Zn (29%) and borax (32%) than soil application which gave 16, 21 and 26 per cent higher yield over control, respectively. These results are also in line with those reported by El-Gharieb *et al.* (1986) and Varma *et al.* (1984).

The increased seed cotton yield in $FeSO_4$ (foliar) could be attributed due to corresponding increase in LA, LAI, number of harvested bolls per plant, mean boll weight, yield per plant and higher uptake of N, P_2O_5 and K_2O. Efficient assimilation of applied micronutrients probably induced better vegetative growth and profuse bearing resulting in marked increase in seed cotton yield over control. Soil application of combination (T_6) gave lower seed cotton yield which may be due to nonavailability of micronutrients and antagonistic effects among one another.

Number of seeds per boll differed significantly among treatments. Foliar application of $FeSO_4$, recorded highest number (30.06) of seeds per boll followed by $FeSO_4$ (soil) (30.00) when compared to 27.4 of water spray and 26.63 of absolute control. Seed index showed non-significant difference. However, foliar application of $MnSO_4$ recorded numerically highest seed index of 9.13 g followed by 9.06 of foliar spray of $CuSO_4$. Ginning out-turn differed significantly among the treatments. Highest ginning per cent was recorded in soil application of combination (T_6) - (43.20), followed by foliar application of borax (40.88) than 37.71 of control. Lint index significantly differed among the treatments. Highest value was recorded in combination (soil - T_6) (6.39) and foliar application of $MnSO_4$ (6.01) as against 5.16 in water spray control.

On the whole, it can be inferred that foliar application of $FeSO_4$, foliar application of $MnSO_4$, combination soil and combination soil treatments responded better for increasing number of seeds per boll, seed index, ginning per cent and lint index respectively. Such results were also reported by El-Gharieb et al. (1986) who found that seed index varied from 11.4 to 12.4 g. But, Ahlawat (1974) reported nonsignificant differences in ginning per cent and Hegab et al. (1983), Srivastava and Singh (1988) reported nonsignificant results in respect of lint index. For increased seeds per boll, the reasons might be due to enhanced synthesis of carbohydrates, proteins and their transport to the site of seed formation. $FeSO_4$ helps in protosynthesis, reduction of nitrates, sulphates and assimilation of nitrogen. Increased ginning per cent and lint index may be due to combined effect of initial soil application of NPK and micronutrients.

5.1.3 Fibre properties

Fibre length, uniformity ratio and micronaire values were non-significant. Maturity coefficient differed significantly among the treatments. $FeSO_4$ - foliar (0.69) and $FeSO_4$ - soil (0.68) recorded higher maturity coefficient over 0.60 of control. Bundle strength also differed significantly by recording highest strength in $MnSO_4$ - foliar (43.96) followed by $MnSO_4$ - soil (42.73) as against 38.76 of control. Such findings were also reported by Srivastava and Singh (1988) and Sawan et al. (1989), whereas Khoddzhaev and Stenyazina (1989), Karev (1980), Kamalanathan (1966) and Hegab et al. (1983) reported significant differences of fibre length, uniformity ratio and micronaire value.

Karev (1980) and Hegab *et al.* (1983) reported significant differences of maturity coefficient and bundle strength. On the contrary, Kamalathan (1966) observed that foliar as well as soil application of $FeSO_4$ influenced fibre fineness, but the bundle strength of fibre was not affected.

5.1.4 Nutrient uptake

Nitrogen uptake by cotton was significantly influenced by foliar application of $FeSO_4$ (134.16 kg/ha) followed by soil application of $FeSO_4$ - 20 kg/ha (132.02 kg/ha) when compared to absolute control (104.36 kg/ha). Significant differences of uptake of P_2O_5 was observed among the treatments. Highest uptake of P_2O_5 was recorded in $FeSO_4$ - foliar (12.60 kg/ha) followed by $CuSO_4$ - foliar (11.63 kg/ha), soil application of combination - T_6 (11.20 kg/ha) as against 7.90 kg/ha of absolute control. For K_2O uptake, significant differences were observed between treatments. Highest uptake of K_2O (156.5 kg/ha) was recorded in foliar application of $FeSO_4$ followed by soil application of $ZnSO_4$ (146.67 kg/ha), $MnSO_4$ - soil (146.33 kg/ha) and $FeSO_4$ - soil (146.33) as against 105.67 kg/ha of absolute control.

On the whole, $FeSO_4$ (foliar) treatment was unique and responded with increased uptake of all the three macronutrients (NPK). Similar results are also given by Kene (1975) in Jowar, Vishwanath (1979) in mulberry and Gangadhara (1988) in sunflower. Higher uptake of N, P_2O_5 and K_2O could be due to the positive influence of micronutrients displaying synergetic effect on growth parameters, physiological traits, dry matter production, yield and yield components.

Further, it may be opined that the cotton plant might have utilised absorbed N for boll formation effectively and this might be the reason why the highest seed cotton yield was obtained with the combined application of NPK and micronutrients. Similarly, higher uptake of P_2O_5 and K_2O could be attributed to the combined effect of absorption and translocation due to the application of micronutrients and nitrogen (Vishwanath, 1979).

Results of Practical Utility

1. Though the initial soil status contains 7.4 ppm of Fe, cotton responded better for foliar application rather than soil which is an easy source of getting nutrient. $FeSO_4$ (foliar) recorded the highest increase in seed cotton yield (902 kg/ha or 58%) over control followed by $ZnSO_4$ - foliar (861 kg/ha - 56%) and $CuSO_4$ - foliar (793 kg/ha - 51 %). These results have to be confirmed by repeating the experiment for one or two more years before they can be recommended for general adoption.

2. Soil application of borax (10 kg/ha) responded better for increase in seed cotton yield of 747 kg/ha (48%) over control followed by $CuSO_4$ - soil (645 kg/ha or 42%) and $ZnSO_4$ - soil (644 kg/ha or 42%). These results can be recommended for general adoption by repeating the experiment if necessary for confirming the results.

3. Even though, both soil and foliar application of micronutrients increased the seed cotton yield over water spray/control, relatively foliar application was found more efficient. Hence, it is possible to combine the micronutrients with insecticidal sprays if not toxic. Compatibility needs investigation.

4. As small doses of all the micronutrients tried increased the yield of seed cotton substantially, they can be recommended for general adoption either through soil or by foliar application.

Future Line of Work

1. Determination of the optimum doses of micronutrients for the cotton crop is essential to avoid toxicity caused due to excess application.

2. Since response of cotton is better for foliar application than soil application, half through soil and half foliar is to be tried to see if this is more beneficial than entire soil application of micronutrients or entire foliar spray.

3. Residual effect of micronutrients on succeeding crops needs to be studied in cotton with reference to soil application.

4. Cost-benefit ratio to be worked out by applying various quantities of different micronutrients either through soil and/or by foliar spray.

5. Areas of micronutrient defficiencies need to be demarkated by analysis of soil samples collected from major cotton growing areas.

6. The possibility of combining micronutrients with insecticidal sprays needs to be studied to find out their compatibility and to decrease the cost of cultivation.

CHAPTER - VI

SUMMARY

VI. SUMMARY

A field experiment was conducted on medium black clay soil under rainfed conditions, at the Agricultural Research Station, Dharwad Farm, during the year 1991-92 to study the response of cotton cv. Abadhita to soil and foliar application of micronutrients. The experiment was laid out in a randomised block design with three replications. The treatments consisted of five micronutrients (Cu, Mn, Fe, Zn and B) applied to soil and through foliar spray individually and in combination. Doses used for soil applicatn were 20 kg/ha in case of $CuSO_4$, $MnSO_4$, $FeSO_4$ and $ZnSO_4$, whereas borax was applied at 10 kg/ha. Foliar application of the micronutrients was done @ 5 kg/ha each except borax which was applied @ 2.5 kg/ha. Foliar applications were made in two equal instalments viz., at 60 and 90 DAS and water spray and control were also included making a total of 14 treatments. AAcommon dose of NPK (40:20:20 kg/ha) was applied to the soil before sowing of the crop for all the 14 treatments. Observations on growth and yield and yield parameters were recorded at 45, 75, 105 and 135 DAS. Uptake of N, P_2O_5 and K_2O at 135 DAS by whole plant analysis was determined.

The results obtained are summarised below:

Significantly highest plant height (22.20 cm) was recorded in soil application of $MnSO_4$ followed by soil application of borax (21.94 cm) and foliar application of combination (21.63 cm) at 45 DAS. At 75 DAS, soil application of borax recorded significantly highest plant height of 90.50 cm. At 105 DAS also, soil application of borax recorded highest plant height. Both soil and foliar application of $CuSO_4$ and F_eSO_4 were effective in increasing the plant height. However, at 135 DAS differences in plant height were not significant.

Number of monopodial branches per plant as influenced by soil and foliar application of micronutrients was found non-significant for all the three stages (75, 105 and 135 DAS).

Number of sympodial branches per plant showed significant differences at 75 and 105 DAS. At 105 DAS, soil application of borax, combination - soil and foliar application of $ZnSO_4$, combination - foliar and soil application of $CuSO_4$ recorded higher number of sympodial branches per plant, indicating that both soil and foliar application of micronutrients were effective in increasing the number of sympodial branches. However, highest number of sympodial branches were recorded in $ZnSO_4$ - soil (12.66) as against 9.50 in control.

Number of leaves per plant were less at 45 DAS but reached the peak at 105 DAS and started decreasing later because of onset of senescence. At 105 DAS, combination - foliar recorded the highest of 148 leaves per plant followed by combination - soil (145.33).

Leaf area per plant (dm^2) was lower at initial stage (45 DAS) and showed non-significant difference. At 75 DAS leaf area per plant was significantly higher in soil application of $FeSO_4$ followed by soil application of borax, foliar application of combination, water spray control, soil application of combination, foliar application of $FeSO_4$ and soil application of $CuSO_4$. At 105 DAS leaf area increased in combination - soil (45.98), $CuSO_4$ - soil (41.86) and $CuSO_4$ - foliar (40.98). $FeSO_4$ and $ZnSO_4$ increased the leaf area per plant throughout the crop period (45 to 135 DAS) when applied by foliar spray.

Significantly higher leaf area index (LAI) was recorded in soil application of $FeSO_4$ (2.285) and borax (2.215) at 75 DAS. Leaf area index was found to fluctuate without any definite trend at 105 and 135 DAS.

Significantly higher absolute growth rate (AGR) was recorded in $ZnSO_4$ - soil (2.48), $MnSO_4$ - soil (2.10) and $CuSO_4$ - foliar (1.60) at final stage (135 DAS). Constant increase in AGR was noticed throughout the crop period (45-135 DAS) when $ZnSO_4$ and $MnSO_4$ were applied as soil application.

Significantly highest relative growth rate (RGR) was recorded between 45-75 DAS period and there was continuous decrease in RGR from 76-135 DAS period.

Significantly highest stem dry matter accumulation was observed in soil application of $CuSO_4$ (59.75 g) followed by borax - soil (58.4 g) and $CuSO_4$ - foliar (59.35 g) at 105 DAS. Whereas at 135 DAS, soil application of micro-nutrients numerically increased the stem dry matter accumulation when compared to foliar applied treatments and controls. Soil and foliar application of combination (T6 and T12) produced moderate stem dry matter accumulation.

Soil application of borax recorded significantly highest (20.83 g) leaf dry matter production followed by combination - soil (19.75 g), $FeSO_4$ - soil (18.08 g) and combination - foliar (18.00 g) at 75 DAS. At 105 DAS, significantly highest leaf dry weight was recorded in combination - foliar (42.85 g) followed by $ZnSO_4$ - foliar (37.50 g), $CuSO_4$ - soil (34.35 g) against absolute control (23.00 g). Whereas at 135 DAS, there was decreasing trend of leaf dry matter production because of defoliation of older leaves from the plant.

Dry matter accumulation in fruiting parts was significantly highest at 135 DAS and soil application of $ZnSO_4$ recorded the highest dry weight (65.3 g) followed by $MnSO_4$ - soil (56.3 g) and $CuSO_4$ - foliar (52.8 g), while soil application of $CuSO_4$ recorded lowest dry weight of fruiting parts per plant among the different micronutrients tested.

Foliar application of $CuSO_4$, soil application of $ZnSO_4$, $MnSO_4$ and foliar aplication of $ZnSO_4$ and $FeSO_4$ were significantly more effective in increasing the total dry matter production per plant. Lowest total dry matter per plant was recorded in control and water spray.

Number of squares per plant was significantly higher in soil application of combination (36.83), foliar application of $CuSO_4$ (33.16) and soil application of $CuSO_4$ (33.0) at 105 DAS. Continued formation of squares was observed in foliar sprayed treatments than soil application indicating that foliar sprays were effective for the continued production of squares. Soil application of $ZnSO_4$ recorded less number of squares (22.0) as against foliar application of $ZnSO_4$ (26.00). Higher number of squares per plant was recorded in both soil and foliar application of $CuSO_4$, $MnSO_4$, $FeSO_4$ and $ZnSO_4$.

Number of green bolls per plant differed significantly among various treatments of micronutrient application at 105 and 135 DAS. At 105 DAS, significantly higher number of green bolls per plant was recorded in $FeSO_4$ - soil (17.0), $FeSO_4$ - foliar (15.66), soil application of combination (14.33), $CuSO_4$- soil (13.33) and combination - foliar (12.33) when compared to 6.50 of water spray, whereas at 135 DAS, significantly higher number of green bolls was recorded in $FeSO_4$ - soil (24.83), $ZnSO_4$ - soil (20.83) and $CuSO_4$ - foliar (20.50) as against 9.50 of absolute control.

Number of harvested bolls per plant showed significant differences. Significantly highest number of harvested bolls per plant was recorded in foliar application of $MnSO_4$ and $FeSO_4$ - foliar (each 12.33) followed by $ZnSO_4$ - foliar (11.80) as against 6.50 of absolute control. Soil application of $ZnSO_4$ recorded 10.20 harvested bolls per plant followed by Borax - soil (10.00) and $CuSO_4$ - soil (9.86) when compared to 6.50 of absolute control.

Numerically highest mean boll weight (4.50 g) was recorded in soil application of borax, followed by 4.47 g in foliar application of $CuSO_4$ as against 3.88 g in water spray.

Significantly highest yield per plant (49.33 g) was recorded in foliar application of $FeSO_4$ when compared to absolute control (26.93). Soil application of $FeSO_4$ recorded 33.36 g yield per plant as against 26.93 g of absolute control. On the whole, foliar application of micronutrients was better than soil application.

Significantly highest yield of seed cotton (2446 kg/ha) was harvested in foliar application of $FeSO_4$ followed by foliar application of $ZnSO_4$ (2405 kg/ha) and $CuSO_4$ (2337 kg/ha) as against 1544 kg/ha of absolute control. Soil application of micronutrients recorded lower seed cotton yield than foliar application. Foliar application of $FeSO_4$, $ZnSO_4$, $CuSO_4$, borax, $MnSO_4$ and their combination increased seed cotton yield from 30 to 58 per cent as against 34 to 48 per cent of soil application of micronutrients.

Number of seeds per boll was significantly higher in $FeSO_4$ - foliar (30.06) followed by $FeSO_4$ - soil (30.0) and $MnSO_4$ - foliar (29.30) against 26.63 of control.

Seed index was nonsignificant. However, numerically highest seed index (9.13 g) was recorded in $MnSO_4$- foliar, followed by $CuSO_4$ - foliar (9.06 g) as against 8.30 g of absolute control.

Soil application of combination recorded significantly highest ginning percentage (43.20) when compared to water spray and absolute control (39.12 and 37.71 respectively).

There was considerable increase in lint index in case of soil application of combination (6.39) and $MnSO_4$ - foliar (6.01) as against 5.48 of absolute control and 5.16 of water spray.

Mean fibre length did not differ significantly. However, soil application of combination, $ZnSO_4$ and $CuSO_4$ recorded numerically higher mean fibre length, whereas soil application of combination recorded highest mean fibre length among the soil application of micronutrients.

Fibre uniformity ratio was not significant among the treatments. Both soil application of combination of micronutrients and foliar application of $ZnSO_4$ recorded 50 per cent uniformity ratio.

Likewise micronaire also did not differ significantly between treatments. However, soil application of $FeSO_4$, foliar application of $MnSO_4$ and combination foliar recorded higher micronaire value (all 3.36) as against 3.06 of control.

Significantly highest maturity coefficient was recorded in foliar application of $FeSO_4$ (0.69) and soil application of $FeSO_4$ (0.68). These two treatments showed significant effect over remaining treatments including water spray control and absolute control.

Significantly higher bundle strength was recorded in foliar spray of $MnSO_4$ (43.96) and soil application of the same element (42.73). Soil application of combination recorded lower bundle strength (40.63) among the different treatments when compared to absolute control (38.76). $FeSO_4$, 5 kg/ha - foliar recorded significantly highest uptake of nitrogen (134.16 kg/ha) followed by $FeSO_4$, 20 kg/ha - soil (132.43 kg/ha), $CuSO_4$, 20 kg/ha - soil (130.33 kg/ha) and $CuSO_4$, 5 kg/ha - foliar (130.41 kg/ha), as against 104.36 Kg/ha of Control.

Significantly highest phosphorus uptake was recorded in foliar spray of $FeSO_4$ (12.60 kg/ha) followed by foliar application of $CuSO_4$ (11.63 kg/ha) and soil application of combination (11.2 kg/ha), as against 7.90 Kg/ha of Control.

Potassium uptake was also significantly highest in case of $FeSO_4$ - foliar (156.5 kg/ha) followed by $MnSO_4$, $MnSO_4$ and $FeSO_4$ - (20 Kg/ha as soil application) which recorded 146.67, 146.33 and 146.33 kg/ha K_2O, respectively, as against 105.67 Kg/ha of Control.

CHAPTER - VII

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VII. REFERENCES

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*Original not seen.

APPENDICES

APPENDIX-1. Physical and chemical properties of soil of experimental site

Particulars	Depth of profile		Method employed
	0-15cm	15-30 cm	
I. Physical properties			
Particle size distribution (expressed in percentage)			
i. Coarse sand	7.64	5.42	Hydrometer method (Sankaran, 1966)
ii. Fine sand	11.50	9.40	-do-
iii. Silt	17.30	17.68	-do-
iv. Clay	61.50	62.04	-do-
II. Chemical properties			
i. pH (1:2.5 soil water suspension)	8.00	8.00	pH meter method (Jackson, 1967)
ii. Electrical conductivity (dSm^{-1})	0.29	0.30	Conductivity bridge method
iii. Cation exchange capacity (C.mol/kg)	60.50	64.20	Sodium saturation method(Black,1965)
iv. Organic carbon (%)	0.50	0.40	Walkey and Black's wet oxidation method (Jackson, 1967).
v. Calcium carbonate (%)	3.40	5.50	Acid neutralization method (Piper,1950)
vi. Available nutrient status			
a. Available N ($kg\ ha^{-1}$)	218	202	Alkaline permanganate method(Subbaiah and Ajija, 1956)
b. Available P ($kg\ ha^{-1}$)	26.5	18.40	Olsen's method (Black, 1965)
c. Available K ($kg\ ha^{-1}$)	371.60	302.50	Flame photometer method (Black,1965)
d. DTPA extractable Zn (ppm)	2.63	1.22	DTPA method (Lindsay and Narvell, 1978)
e. DTPA extractable Fe (ppm)	7.40	7.30	-do-
f. DTPA extractable Mn (ppm)	24.13	21.23	-do-
g. DTPA extractable Cu (ppm)	2.29	2.11	-do-
h. DTPA extractable B (ppm)	0.97	0.74	Carmine sulphuric acid method (Berger and Truog, 1939 and modified by Wear,1965)

APPENDIX-II. Quantity of micronutrients applied to soil and foliar spray (as per treatments)

S.No.	Treatment	Method of application	Dosage of micro-nutrients (kg/ha)	Quantity/ plot (g)(SA)	Quantity/ plot (g)(FS)	
					I (60DAS) (2.5 kg/ha)	II (90 DAS) (2.5 kg/ha)
1	$CuSO_4$	Soil application (SA)	20	64.8	-	
2	$MnSO_4$	-do-	20	64.8	-	
3	$FeSO_4$	-do-	20	64.8	-	
4	$ZnSO_4$	-do-	20	64.8	-	
5	Borax	-do-	10	32.4		
6	Combination of all five	-do-	90	291.6	-	
7	$CuSO_4$	Foliar spray (FS)(60 and 90 DAS)	5.0	-	8.10	8.10
8	$MnSO_4$	-do-	5.0	-	8.10	8.10
9	$FeSO_4$	-do-	5.0	-	8.10	8.10
10	$ZnSO_4$	-do-	5.0	-	8.10	8.10
11	Borax	-do-	2.50	-	4.05	4.05
12	Combination of all five	-do-	22.5	-	36.45	36.45
13	Water spray (control)	-	-	-	1543*	2160*
14	Absolute control	-	-	-	-	-

NOTE

1. Recommended dose of 40:20:20 NPK kg/ha (70 kg urea; 43.5 kg DAP; 33.33 kg MOP) was calculated to per plot (32.4 m^2), mixed and applied for each treatment at 227 g urea, 141 g DAP and 108 g MOP. Micronutrients applied as per treatments as soil application before sowing (T_1 to T_6).

2. Foliar application of micronutrients in two equal splits at 60 DAS (16.9.91) and 90 DAS (14.10.91) (T_7 to T_{12}).

3. Quantity of water used at 60 DAS (1543 l/ha) and 90 DAS (2160 l/ha).

APPENDIX-III. Schedule of plant protection measures adopted during experimentation

Sl. No.	Date	Chemical used	Dosage	Against
1	20.8.1991	Rogor-30 EC	30 ml in 18 l. water	Aphids and thrips
2	10.9.1991	Nuvacron-40EC	40 ml in 18 l. of water	Bollworms and semiloopers
3	19.9.1991	Endosulfan-35 EC	50 ml in 18 l. water	Bollworms
4	1.11.1991	Endosulfan-35 EC	50 ml in 18 l. water	Bollworms