INFLUENCE OF IRRIGATION, FYM AND SULPHUR ON GROWTH, YIELD AND QUALITY OF CHICKPEA (*Cicer arientinum* L.) UNDER MIDDLE GUJARAT CONDITIONS

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ABSTRACT

INFLUENCE OF IRRIGATION, FYM AND SULPHUR ON GROWTH, YIELD AND QUALITY OF CHICKPEA (*Cicer arientinum* L.) UNDER MIDDLE GUJARAT CONDITIONS

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ABSTRACT

A field experiment was conducted at Regional Sugarcane Research Station, Gujarat Agricultural University, Thasra during *rabi* season of the year 2002-03 to study the "Influence of irrigation, FYM and sulphur on growth, yield and quality of chickpea under middle Gujarat conditions". The soil of the experimental plots was sandy clay loam in texture having good drainage with 7.9 pH. The soil was low in organic matter and available nitrogen, while medium in available phosphorus and high in available potassium. The experiment comprised of two levels of irrigation viz., I_0 (only pre-sowing irrigation) and I_1 (Pre sowing irrigation plus irrigation at flowering stage) and FYM viz., F_0 (0 tones FYM ha^{-1}) and F_1 (10 tonnes FYM ha^{-1}) in main plots and three levels of sulphur (S_0: 0, S_1: 20, S_3: 40 kg S ha^{-1}) in sub plots. The experiment was laid out in split plot design with four replications.

Most of the growth parameters studies during the course of investigation such as plant height, number of branches per plant, number

of nodules and dry weight of nodules per plant showed significant improvement due to application of supplemental irrigation at flowering stage with pre-sowing irrigation. Perusal of these data in general indicated that the maximum vegetative growth was achieved by application of two irrigations each at pre-sowing and at flowering stage (I_1).

Increased vegetative growth due to irrigation application had brought concomitant improvement in yield attributes and finally in the yield. The yield attributes viz., number of pods per plant, grain yield per plant, test weight and total grain and straw yields were significantly improved by irrigation applied at pre-sowing and one supplemental irrigation at flowering stage. On the contrary, variation in harvest index due to irrigation treatment was absent.

Among the quality parameters, nitrogen, protein and sulphur contents in grain were significantly enhanced under pre and post sowing irrigation treatment.

The differences in post harvest available soil nutrients like nitrogen, potassium and sulphur were unaltered by irrigation schedule but post harvest available phosphorus was recorded significantly higher under the application of irrigation at pre-sowing plus irrigation at flowering stage than application of pre-sowing irrigation alone.

Further, irrigation schedule at pre-sowing and post sowing (at flowering stage) tended to recorded higher moisture content at flowering (50 DAS) and pod development stage than irrigation at sowing only.

Growth parameters such as plant height, number of branches per plant, number of nodules and dry weight of nodules per plant were significantly increased due to application of FYM. Profound vegetative growth due to FYM application had resulted into significantly more number of pods per plant, grain yield per plant, test weight and there by more grain and straw yields. Whereas, variation in harvest index due to FYM was absent.

The nitrogen and protein contents in grain were also improved significantly by FYM application. Whereas, sulphur content in grain remains unaffected due to FYM application. Further, the FYM application tended to increase the post harvest available soil nitrogen and phosphorus significantly. Available soil potassium and sulphur contents did not differ significantly due to FYM application.

Application of FYM also found beneficial in moisture retention of soil. FYM significantly improved the soil moisture content recorded at flowering (50 DAS) and pod development stages (90 DAS).

Sulphur application in chickpea had significant effect on almost all attributes studied during the course of investigation, wherein S_2 (40 kg S ha^{-1}) showed significant superiority over S_1 (20 kg S ha^{-1}) and S_0 (0 kg S ha^{-1}) in plant height recorded at 60 DAS, number of nodules and dry weight of nodules per plant. While, number of branches per plant, number of pods per plant, grain yield per plant, test weight as well as total grain and straw yields were significantly improved up to S_1 (20 kg S ha^{-1}).

Further application of sulphur (40 kg S ha^{-1}) was not found beneficial in these parameters.

Plant height recorded at harvest did not differ significantly due to sulphur application.

Application of sulphur @ 40 kg S ha^{-1} recorded significantly higher nitrogen, protein and sulphur contents in grain over 20 kg S ha^{-1} and 0 kg S ha^{-1}.

The difference in post harvest available soil nutrients like nitrogen, phosphorus and potassium was not observed due to sulphur application. While, the post harvest S content noted significantly higher under 40 and 20 kg S ha^{-1} over 0 kg S ha^{-1}.

Further, moisture content in soil at flowering stage (50 DAS) noted significantly highest under by 40 kg S ha^{-1}. While, at pod development stage (90 DAS) it was remain unaffected due to sulphur treatment.

From the foregoing results, it is pertinent that chickpea variety ICCC-4 gave highest yield as well as net return when it was irrigated two times (at pre sowing and flowering stage) with application of FYM @ 10 tonnes ha^{-1} and sulphur @ 40 kg ha^{-1}.

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CERTIFICATE

This is to certify that the thesis Entitled "**INFLUENCE OF IRRIGATION, FYM AND SULPHUR ON GROWTH, YIELD AND QUALITY OF CHICKPEA (*Cicer arientinum* L.) UNDER MIDDLE GUJRAT CONDITIONS**" submitted by **Mr. RAJNIKANT ARJANBHAI PATEL** in partial fulfillment of the requirements for the degree of **Master of Science (Agriculture) in Agronomy** of the Gujarat Agricultural University is a record of bonafide research work carried out by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Place: ANAND

(Dr. R. H. Patel)
MAJOR ADVISOR

Date: 18/8/2004

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LIST OF ABBREVIATIONS

Anon.	Anonymous
@	At the rate
^0C	Degree celsius
C.B.R.	Cost benefit ratio
C. D.	Critical difference
cm	Centimeter
CPE	Cumulative pan evaporation
cv.	Cultivar
C.V.	Co-efficient of variation
DAS	Days after sowing
et al.	Et allii: and others
Fig.	Figure
g	Gramme
ha	Hectares
HI	Harvest index
Hr.	Hour
i.e.	That is
Kg	Kilogramme
m	Meter
Max.	Maximum
mg	Milligramme
Min.	Minimum
N	Nitrogen
No.	Number
NS	Non significant
%	Per cent
q	Quintal
R.H.	Relative humidity
Rs.	Rupees
S.Em.$\pm$	Standard error of mean
t	Tonne
Var.	Variety
viz.	Namely

INTRODUCTION

I. INTRODUCTION

Pulses are an important component of food grain crops because of their high nutritive value (protein content ranging from 17-27 per cent), inherent capacity to fix atmospheric nitrogen and adaptability to a wide range of agro ecological, cropping system and management variables. In India, total area of pulses is 23.26 million hectares which produces about 13.7 million tones, with an average of 589 kg ha^{-1} (Bhan and Mishra, 1998) which is comparatively very low to the average pulse yield of 852 kg ha^{-1} of the world (Anon, 1993).

Chickpea (*Cicer arientinum* L.) commonly in English known as bengal gram and locally Chana, is an important food legume. India is a premier chickpea growing country accounting 76% of total area and production of the world (Anon, 1992). India occupies 7.54 million hectares of land with average production of 6.13 million tones and productivity of 812 kg ha^{-1}. In Gujarat, chickpea is grown in an area of 0.14 million hectares, producing 0.12 million tones with productivity of 871 kg ha^{-1} (Anon, 1999). It occupies about 8.12% of the total pulse cultivation in Gujarat. The otal area, production and productivity of chickpea crop in Kheda district in the year 1997-98 was 5400 ha, 3500 metric tones and 655 kg ha^{-1}, respectively (Anon, 1998).

Augmenting the production of pulse crops is not only essential for providing protein rich food grains at reasonable cost to human and farm cattle but also for overall productivity and conservation of Indian agriculture. The productivity of chickpea per unit time and area can be increased by adopting appropriate agronomic practices such as selecting suitable high yielding variety, irrigation and moisture conservation practices and prudent nutrient management.

Water is the basic input for increasing crop production. Agricultural productivity cannot be maintained without assured supply of moisture to the plant, which is accomplished by irrigation. Even though chickpea thrives well under scarcity moisture condition, it responds well to irrigation (Saxena, 1984). The crop responds invariably to irrigation. Though each crop has certain critical stage at which adequate moisture required for proper crop growth. Hence, efficient water management is the key factor for boosting crop production. Knowledge of critical stage of water use by chickpea crop during its growth period is essential for judicious application. The importance of critical stage of crop growth for irrigation needs of the crop, particularly under middle Gujarat conditions, does not seem to have received due importance so far.

To compensate the short supply and recent price hike in inorganic fertilizers, use of indigenous sources like Farmyard manure (FYM) should be advocated. It not only supplies all the major and micronutrient, but also acts as a soil conditioner improves physico-chemical properties of soil and encourages the soil microbial activities too.

It is quite useful particularly under limited water availability situations as it increase the water retention capacity of soil. Increase in nutrient availability especially of nitrogen is also noted with inoculation of FYM in the soil and it is advantageous for its residual value.

Sulphur is most important nutrient after N, P and Zn for Indian agriculture. It is also needed in large amount by pulse crops and its deficiency in India is widely spread particularly in high intensive cropping. It is the element that is essential for synthesis of protein, vitamins and S containing essential amino acids viz. methionine cystine and cysteine. Sulphur also markedly enhanced the content of P, S, and protein in grain and ultimately the yield and quality of legumes. Fertilization with it, promotes roots and nodule development in chickpea. The increase in yield and growth parameters is due to the role of sulphur in carbohydrate metabolism, energy transformation and chlorophyll synthesis.

Meager information is available on the above aspects so far as their combine effect is concerned. Therefore keeping all these in view a study on the Influence of irrigation, FYM and sulphur on growth, yield and quality of chickpea (Cv. ICCC-4) under middle Gujarat conditions an experiment was conducted during the year 2002-03 at Regional Sugarcane Research Station, Gujarat Agricultural University, Thasra. Dist Kheda with following specific objectives :

1. To find out the response of pre and post sowing irrigation (at flowering stage) on growth and yield of chickpea.
2. To assess the effect of FYM on chickpea.
3. To study the influence of sulphur on growth, yield and quality of chickpea.
4. To study the interaction effect of irrigation, FYM and sulphur treatment for chickpea.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Continuous attempts are being made to ascertain the proper scheduling of irrigation and inorganic and organic fertilizer management of chickpea to increase the yield in chickpea growing regions of different states in India and abroad. Efforts are therefore, being made to present in this chapter a brief summary of studies carried out at various places, related to present investigation. The review has been highlighted under following heads.

2.1 Effect of irrigation

2.2 Effect of farmyard manure

2.3 Effect of sulphur

2.1 EFFECT OF IRRIGATION

Water is essential for every biological system. It is important for physiological requirements of crop growth as well as nutrient management in crop production. As water is scare and costlier input, critical growth stage approach for irrigation seems to be more efficient, economical, simple and easy for farmers. The work pertinent to irrigation schedule has been reviewed as under:

Yadav (1972) at Hisar (Haryana) concluded that gram gave 300-400 kg extra grain yield due to one irrigation given either at per-flowering (45 DAS) or at flowering (70 DAS) stage over rainfed crop on sandy loam soil.

The result of an experiment conducted at Parbhani by Raikherkar *et al.* (1977) concluded that grain yield of chickpea was increase significantly due to two irrigations applied at 45 and 75 DAS over one irrigation under black soil.

Sinha and Singh (1977) conducted an experiment at Nigina, (Rajasthan) on clay loam soil and reported that one irrigation either at 45 DAS or at 75 DAS significantly increased the grain and straw yields of chickpea over with no irrigation.

Sandhu *et al.* (1978) reported that application of irrigation at 0.6 and 0.8 IW/CPE ratios significantly increased the plant height and straw yield over 0.4 IW/CPE ratio and control, whereas, number of pods per plant, test weight and grain yield were remained unaffected due to irrigation treatment under sandy loam soil in Punjab. They further concluded that more frequent irrigation increased the vegetative growth of the crop.

An experiment was conducted by Mandal *et al.* (1979) to find out an appropriate schedule of irrigation to gram crop at Sabour (Bihar) during 1973-74 on sandy loam soil. From the results, they found that two irrigations each applied at branching and flowering stages significantly increased the plant height, number of branches per plant, number of pods per plant, test weight and grain yield over no irrigation, whereas, straw yield increased significantly with one irrigation applied at pre flowering or at dough stage. They further reported that more than two irrigations did not prove to be beneficial on other hand these affected the yield adversely.

Singh *et al.* (1980) conducted an experiment on sandy loam soil at Hisar and reported that one irrigation at 45 DAS significantly increased the grain yield of gram over no irrigation either at 75 DAS or at early pod-filling stage during two years of experimentation. Two irrigation's (45 and 75 DAS) were found inferior in respect to yield and yield attributes than one irrigation at 45 DAS.

Yusuf *et al.* (1980) while working at IARI, New Delhi during 1970-71 and 1971-72 on sandy loam soil and found that one irrigation applied at seedling stage and two irrigations given at seedling and flowering stages significantly increased the gram grain yield over unirrigated control and irrigation given at more than two growth stages during both years of experimentation.

Bhan and khan (1982) reported that one irrigation at pre flowering stage or two irrigations at pre-flowering and grain filling stages markedly improved the plant height, number of branches per plant, number of grains per pod, test weight and grain yield over no irrigation under light textured alluvial soil at Kanpur (U.P).

Dumbre and Deshmukh (1983) indicated that two supplementary irrigations (45 and 75 DAS) with pre-sowing irrigation significantly increased the grain yield of gram over only pre-sowing irrigation under clay loam soil of Rahuri (Maharashtra) during two years of experimentation.

The result of an experiment conducted on clay loam soil at Jabalpur (M.P) during 1975-76 and 1976-77 indicated that application of one irrigation (45 DAS) significantly increased grain yield of gram as compared to no irrigation and one irrigation at 75 DAS. Two irrigations given at 45 and 75 DAS produced the maximum grain yield (Raghu and Choubey, 1983).

Grewal *et al.* (1984) while working at Chandigarh found that plant height, number of grains per pod, 1000-grains weight, straw and grain yields were not influenced significantly due to irrigation treatments (one irrigation at flowering, at pod formation and two irrigation at flowering and pod formation stages). However, these characters were increased marginally due to irrigation over with no irrigation under sandy loam soil.

Katare and Bhale (1984) conducted an experiment on the effect of number of irrigation at different crop growth stages on yield of gram at Badnapur (Maharashtra), found that the gram crop favourably responded to the application of irrigation water. The yield under one irrigation either at flowering or at pod formation stage did not differ significantly among themselves, however, it was about 25 percent higher than with no irrigation.

Poonia (1984) at Bonswara (Rajasthan) concluded that irrigation significantly increased the grain yield of gram over no irrigation under clay loam soil. Two irrigations, one at flowering and another at pod formation stages gave maximum grain yield (13.0 q ha^{-1}) followed by one irrigation at flowering stage (10.5 q ha^{-1}). While in another study at the same location, Singh (1984) observed maximum grain yield under one irrigation at pre-flowering stage (45 DAS) which was found at par with two irrigations given at pre-flowering and pod filling stages during two years of study.

Dobariya *et al.* (1985) observed that number of pods per plant, test weight and grain yield of chickpea did not differ significantly due to different IW/CPE ratios (0.3, 0.4 and 0.5) under clayey soil at Junagadh.

Kushwaha *et al.* (1985) while working at Indore (M.P) reported that irrigation applied at 45 DAS gave significantly higher grain yield of chickpea than that applied at 75 DAS and no irrigation.

Naresh *et al.* (1985) at Panthagar indicated that one irrigation applied at 90 DAS significantly increased grains per pod, test weight and grain yield over no irrigation, whereas, significantly the highest straw yield was recorded when two irrigations applied at 90 DAS and 120 DAS.

The result of an experiment conducted by Palled *et al.* (1985) reported that irrigating the gram crop at 0.8 IW/CPE ratio throughout the crop growth period which required six irrigations significantly increased the number of pods per plant, test weight and grain yield over control under Dharwad conditions having deep black soils.

Roy and Tripathi (1985) conducted an experiment for two years (1980-81 and 1981-82) at Kharagpur (W.B.). They observed that 0.6 IW/CPE ratio was found at par with 0.4 IW/CPE ratio in grain yield of chickpea but significantly superior to two irrigations given at branching and pod formation stages during first year. However, in second year, 0.4 IW/CPE ratio was at par with irrigation schedule at branching and pod formation stages and both were significantly superior to 0.6 IW/CPE ratio. Irrigation at 0.6 IW/CPE ratio recorded significantly higher straw yield over 0.4 IW/CPE ratio in both the years.

Shinde et *al.* (1985) at Rahuri reported the maximum grain yield of chickpea (25.13 q ha^{-1}) with three irrigations, one at pre-flowering, second at branching and third at pod development stages under medium black soil.

An experiment was conducted on Kabuli gram at Hisar (Haryana) on sandy loam soil by Borgohain and Agarwal (1986) with three levels of irrigation (no irrigation, one irrigation at ID/CPE 0.2 and two irrigations ID/CPE 0.4). Results showed that one irrigation based on ID/CPE 0.2 increased the grain yield by 15.2 and two irrigations at 0.4 ID/CPE by 28.0 per cent over with no irrigation.

A field experiment was conducted by Maity and Jana (1987) on clay soil during 1975-76 and 1976-77 indicated that grain yield of gram obtained higher under irrigation applied at pre-flowering stage than unirrigated control in both the years. Test weight was not affected significantly due to irrigation.

Ramshe *et al.* (1987) while working at Rahuri (Maharashtra) on clay loam soil during 1982-83, 1983-84 and 1984-85 reported that maximum grain yield of chickpea under three irrigations applied at branching, flowering and pod filling stages. This increase in grain yield was 19 per cent higher than application of one irrigation at flowering.

Kulhare *et al.* (1988) conducted an experiment on deep vertisol of Powerkheda (MP) during 1982-83 and 1983-84 reported that irrigations scheduled at 0.8 IW/CPE ratio gave significantly higher grain and straw yields than those at 0.4 and 0.6 IW/CPE ratios and control.

Meisheri (1988) conducted an experiment on silty clay loam soil of Arnej (Gujarat) for two years. He observed that one irrigation at pre flowering stage and two irrigations at pre-flowering and flowering stages significantly increased the grain yield and harvest index over control. The author further reported that marginal increase in plant height, number of branches per plant, number of flower per plant, number of pods per plant, pod length, number of grains per pod and 100 seed weight was due to application of one irrigation at pre-flowering or two irrigations at pre-flowering and flowering stages over control.

Roy *et al.* (1988) at Bhagalpur (Bihar) conducted the experiment to study the effect of irrigation on yield of late sown chickpea and reported that single irrigation applied during the period from 45-50 DAS or at pod initiation found more beneficial to recording higher grain yield than with no irrigation.

Patel *et al.* (1989) conducted an experiment at Junagadh to study the response of chickpea to irrigation based on IW/CPE ratio (0.3, 0.4 and 0.5) and reported that scheduling irrigation based on IW/CPE ratio of 0.5 recorded significantly higher grain and fodder yields of chickpea than 0.3 and 0.4 IW/CPE ratios under clayey soil.

Similarly, Parihar (1990) conducted an experiment on sandy loam soil of Kharagpur (W.B) to study the influence of irrigation schedule (0.4, 0.6 and 0.8) on growth and yield of chickpea for two years. He found that irrigations applied at 0.4 IW/CPE ratio (three irrigations) resulted in significantly higher pods per plant and grain yield of chickpea over 0.6 and 0.8 IW/CPE ratios. Author further reported that frequent irrigation (at 0.6 and 0.8 IW/CPE ratio) apparently encouraged excessive and prolonged vegetative growth without any advantage to grain yield.

A field experiment was conducted by Nimje (1991) at Bhopal (MP) to study the effect of irrigation based on critical growth stages of chickpea in deep vertisol. He found that grain and straw yields of chickpea significantly improved up to 3 irrigations applied at pre-sowing, branching and pod filling stages.

Prabhakar and Saraf (1991) conducted an experiment at New Delhi under alluvial sandy loam soil and observed the maximum plant height, branches per plant and grain yield of chickpea (7 q ha^{-1}) under two irrigations applied at 0.4 IW/CPE ratio.

Pawar *et al.* (1992) at Rahuri (Maharashtra) reported that when two irrigations were available to chickpea, their scheduling at branching (30 days) and at flowering (60 days) was the best, whereas when one irrigation was available its scheduling at flowering stage was better for getting higher yield.

The response of irrigation (no irrigation, irrigation at 0.4, 0.6 and 0.8 IW/CPE ratio) on yield of chickpea by Dixit *et al.* (1993) at Powerkheda (MP) in clayey soil. Results revealed that the maximum grain and straw yields of 18.66 and 71.70 q ha^{-1}, respectively with irrigation at an IW/CPE ratio of 0.8, which were significantly higher than those of lower ratios. The N, P and K uptake in grain and straw were also recorded highest under IW/CPE ratio of 0.8.

Gaur and Chaudhary (1993) conducted an experiment at Udaipur (Rajashthan) in clay loam soil. They found that two irrigations given at pre-flowering and pod-formation stages gave the highest seed yield, which was 115.2 % higher than the control (no irrigation) whereas one irrigation at pre-flowering stage gave 63.6 % more seed yield than no irrigation.

While working at Jabalpur (M.P), Sharma (1994) found that one irrigation either at branching or flowering stage as well as two irrigations at both these stages in addition to pre-sowing irrigation gave significantly higher grain and straw yields than only pre-sowing irrigation under clay loam soil.

The result of an experiment conducted at Raipur (M.P) under clay loam soil by Tiwari and Tripathi (1995) indicated that two irrigations applied at branching and pod formation stages (35 and 75 DAS) gave significantly higher grain yield of gram than no irrigation at either of the stages.

While working at Anand under sandy clay loam soil, Chaudhary et al. (1998) found that two irrigations at flowering and pod development stages gave significantly higher grain yield than no irrigation. It also recorded higher pod length, harvest index and protein content than with no irrigation.

Ghatol *et al.* (1998) at Akola (Masharashtra) observed that the highest yield of gram was recorded with two irrigations at branching and seed development stages and found at par with three irrigations at rosette, branching and seed development stages under clay loam soil.

Maliwal *et al.* (1998) at Arnej (Gujarat) reported that one 50 mm supplemental irrigation at maximum branching in chickpea gave higher yield than no irrigation under silty clay loam soil.

The results of an experiments conducted on a sandy loam soil by Reddy and Ahlawat (1998) during winter season of 1988-89 and 1989-90 at New Delhi indicated that two irrigations applied at branching and pod initiation stages improved the chickpea growth (plant height, dry matter production, leaf area index and nodule mass) and recorded more pods per plant, grain and straw yields, N uptake, protein yield and net returns than with no irrigation.

Field experiments were conducted by Kaushik and Chaubey (1999) during the winter season of 1992-93 and 1993-94 on a sandy loam soil at Ujhani (U.P). The results showed that application of one irrigation at branching (45 DAS) produced significantly higher yield of gram as compared to no irrigation and one irrigation at pre-flowering (75 DAS) or at pod filling stages (105 DAS).

Maliwal *et al.* (1999) conducted an experiment at Khandha (Gujarat) on clay loam soil and reported that two irrigations applied at post sowing (80 mm) and flowering (70 mm) stages gave significantly higher grain yield of chickpea than one irrigation (control) applied at sowing or branching or pod formation stage, but it was remained at par with two irrigations either applied at flowering and pod formation or branching and pod formation stages and also with three irrigations applied at branching, flowering and pod formation stages.

The results of an experiment conducted on sandy loam soil at Anand (Gujarat) by Zala *et at.* (2002) indicated that application of 3 irrigations at branching, flowering and pod development stages recorded the highest number of nodules, pods, grains per plant, test weight, grain yield and protein content of seeds. However, these attributes were at par with that recorded under two irrigations at branching and flowering stages.

2.2 EFFECT OF FARMYARD MANURE

Efficiency of fertilizers can be improved by the use of organic manures, as they are important for holding water and nutrients besides improving the physical condition of soil. The continuous use of only fertilizers may likely create soil health problems with regard to acidity, alkalinity and availability of secondary and micronutrients. Hence, there is a need to integrate the use of organics like FYM along with the fertilizer for concomitant improvement in the soil fertility and productivity. The use of organic manures along with fertilizers not only helped in maintaining the soil fertility but also markedly increased the crop yield (Biswas *et al.*1969).

Raju and verma (1984) at Varanasi, (BHU) conducted an experiment on sandy clay loam soil and reported that incorporation of

FYM increases branching and dry matter production of chickpea over inoculation treatment. However, grain yield was not affected significantly.

Patel and Patel (1991), while working on chickpea at Navasari (Gujarat) observed a non-significant effect of FYM (10 t ha^{-1}) on any of the growth and yield attributes, however, number of branches per plant was significantly increased due to application of 10 tones FYM ha^{-1} over no FYM.

Raju *et al.* (1991) at Varanasi, (BHU) also observed a marginal increase in nodulation in chickpea due to FYM (@ 10 kg N ha^{-1}) over inoculation with Rhizobium. Similarly, higher uptake of N, P and K was also recorded with the application of FYM.

While studying the influence of organic, inorganic and biofertilizer on nodulation of chickpea at Junagadh (Gujarat), Vadavia *et al.* (1991) found that application of FYM (5 tones ha^{-1}) plus Rhizobium inoculation recorded higher number of nodules than alone inorganic fertilizer and Rhizobium inoculation and inorganic fertilizer plus Rhizobium inoculation.

Gangwar and Singh (1992) conducted an experiment at Modipuram (U.P) to study the integrated nutrient management for fodder sorghum-gram cropping sequence and observed that application of FYM @ 6t/ha significantly increased plant height, number of branches and pod per plant, test weight and grain yield of chickpea as compared to control during two years of study.

The results of experiment conducted on chickpea under loamy sand soil of Anand by Shah (1995) revealed significant increase in plant height, number of branches, pod and grains per plant, grain and straw yields and harvest index with the application of FYM (5 t ha^{-1})

Jat and Ahlawat (2002) conducted an experiment at New Delhi on sandy loam soil and observed that application of vermicompost @ 3t ha^{-1} significantly increased the chickpea growth (Plant height, dry matter accumulation per plant, leaf area per plant, number and weight of root nodules per plant) and yield attributes (pods per plant, grain weight per plant and 1000 grains weight), yield and harvest index over no vermicompost.

Meena and Singh (2002) conducted a trial at IARI, New Delhi under sandy loam soil. The experiment consisted four moisture conservation practices viz., control, bunded field, bunded field + FYM @ 10 tones ha^{-1} and bunded field + green manuring. The results revealed that moisture conservation practices through bunded field + FYM application enhanced the yield attributes viz., number and weight of pods per plant, grain yield per plant, grain and straw yields, harvest index, N and P content and uptake and moisture retention in the soil as compared to all other moisture conservation practices during two year of study.

The result of an experiment conducted on alluvial sandy loam soil of IARI New Delhi by Shivakumar *et al* (2002) and showed that the grain yield of chickpea significantly increased with the application of FYM @ 5t ha^{-1} as compared to no FYM under limited water supply conditions.

From the above cited literature it can be concluded that irrespective of location, soil type and soil composition, application of FYM improve the moisture retention in soil, root nodulation, nutrient content in grain, nutrient up take by crop and yield attributes of chickpea.

2.3 EFFECT OF SULPHUR

Sulphur application is a key component of modern pulse production technology. Among different pulse crop, chickpea is a highly responsive crop to sulphur application. Sulphur plays a vital role in the synthesis of protein, oils and vitamins. The important of sulphur in balanced plant nutrition is increasingly realized with increase sulphur deficiency in several area due to intensive agriculture, less addition of organic manures and extensive use of sulphur free fertilizers like urea and diammonium phosphate and various NPK mixtures.

Dwivedi and Singh (1982) conducted the experiment at Kanpur and reported that sulphur increased the per cent of protein and amount of methionine and cystine content in chickpea grain.

At Varanasi, an experiment was conducted in sandy loam soil by Singh and Ram (1989) reported that phosphorus uptake by chickpea increased significantly with increasing levels of sulphur (0, 40, 80 and 120 kg ha^{-1}) upto 80 kg ha^{-1}. Further increase in sulphur dose (120 kg ha^{-1}) did not show perceptible change in uptake of phosphorus.

Singh and Ram (1991) studied the effect of phosphorus (0, 13, 26 and 39 kg P_2O_5 ha $^{-1}$) and sulphur (0, 40, 80 and 120 kg ha^{-1}) application on yield and uptake of phosphorus by chickpea on sandy loam soil of Varanasi (BHU). The result revealed that the maximum yield of chickpea was obtained with the application of 26 kg phosphorus and 80 kg S ha^{-1}. Further application of P and S decreased the yield. Authors further reported that the application of sulphur had a synergistic effect on the content of P in grain and straw to a certain level (80 kg ha^{-1}) of sulphur. Combine application of 26 kg P and 80 kg S ha^{-1} significantly increased the content and uptake of P in grain and straw of the crop.

The application of sulphur sources (gypsum, pyrite and elemental S) at various levels viz., 0, 20, 40 and 60 kg S ha^{-1} affected the yield of chickpea observed by Ram and Dwivedi (1992) at Kanpur in sandy loam soil. Grain yield of chickpea increased markedly with increasing level of S upto 40 kg ha $^{-1}$ in cost of gypsum and pyrite. However, this increasing trend in elemental S was observed at the level of 60 kg S ha^{-1}. Protein, methionine and tryptophan content was significantly higher than the control due to sulphur application.

Ramkala and Gupta (1992) at Hisar (HAU) studied the comparative response of *rabi* pulse crops to sulphur and reported that among pulse grains, the highest increase in grain yield due to sulphur @ 20 mg kg $^{-1}$ soil was observed in lentil (20 per cent) followed by peas (17.5 per cent), fenugreek (15 per cent) and chickpea (12.2) per cent under ustipsamment soil.

At I.A.R.I, New Delhi an experiment conducted in sandy loam soil by Sachdev *et al.* (1992) and reported that seed yield of chickpea increased by about three q ha $^{-1}$ due to sulphur fertilization (60 kg ha $^{-1}$). The amount of protein harvested was 1.6 q ha^{-1} under the application of NPK with sulphur (30 kg ha^{-1}) as against 0.9 q ha^{-1} for the plots given NPK alone and were statistically significant.

Shinde and Saraf (1992) at I.A.R.I., New Delhi conducted experiment in sandy loam soil and reported that sulphur fertilizer promoted roots and nodules development in chickpea. Application of 40 kg S ha^{-1} significantly increased number and nodules dry weight as compare to control.

Joseph and Verma (1994) at Varanasi conducted experiment in black clay soil and concluded that higher rate of sulphur @ 40 kg ha^{-1} significantly increased the yield and yield attributes and nodulation in chickpea over 20 kg S ha^{-1}.

An experiment conducted by Joseph *et al.* (1995) at Institute of Agriculture Science, BHU, Varanasi on sandy clay loam soil and observed that application of higher level of sulphur (40 kg ha^{-1}) resulted in significantly increased in grain yield by 0.82 pre cent over 20 kg S ha^{-1}.

Further application of 40 kg S ha^{-1} also increased the nitrogen and phosphorus status of soil after harvest of crop.

Saraf *et al.* (1997) conducted an experiment on chickpea at New Delhi on alluvial sandy loam soil and reported that the application of sulphur at 40 kg ha^{-1} resulted in significantly higher pods $plant^{-1}$, pods yield $plant^{-1}$, 1000 seeds weight than control.

While working at Kanpur, Tripathi *et al.* (1997) conducted the experiment to study the response of gram to sulphur (0, 20, 40, 60 kg ha^{-1}) under loam typic ustochrept and reported that the highest grain and straw yields as well as the yield attributes where obtained with the application of 40 kg sulphur ha^{-1}.

While working at Ranchi (Bihar), Ghosh and Sarkar (2000) conducted an experiment on sandy loam soil to study the response of chickpea to sulphur (0, 10, 20, 30 and 40 kg S ha^{-1}). They reported that application of 40 kg S ha^{-1} through phosphogypsum significantly increased the grain yield of chickpea than lower levels of sulphur. Total sulphur uptake by chickpea ranged from 13.17 to 15.96 kg S ha^{-1} in sulphur treated plots compared to 9.42 kg S ha^{-1} in control plots. Authors further reported that the per cent recovery of S is higher at lower application rates while the absolute uptake of added S increased with increasing rate of application.

An experiment carried out by Shivakumar (2001) in sandy loam soil at I.A.R.I., New Delhi and reported that application of S with or without P recorded significantly higher seed yield of chickpea upto 40 kg S ha^{-1}. Addition of P with S showed significantly higher seed yield than S alone. Most of the growth and yield attributes also showed the similar trend.

Field experiment was conducted by Kumar and Khangaret (2002) in loamy sand soil of Jobner (Rajasthan) to study the effect of sulphur (0, 20, 40, 60 kg ha^{-1}) on yield and quality of chickpea. The results revealed that the grain and straw yields, protein content in grain and sulphur content in grain and straw where increased significantly with increasing levels of sulphur. The per cent increase in grain yield over control due to 20, 30 and 40 kg sulphur ha^{-1} was 17.99, 32.69 and 46.52 per cent, respectively.

Singh *et al.* (2002) studied the effect of sulphur (0, 20, 40 kg ha^{-1}) on chickpea at Kanpur and reported that the increase in grain yield, protein content and sulphur content in grain was not found significant with more than 20 kg sulphur application under calcareous alkaline soil.

While working at Gwalior (JNKVV) on sandy loam soil, Kaprekar *et al.* (2003) reported that application of 60 kg S ha^{-1} gave significantly higher grain and straw yields of chickpea over no sulphur application. Authors further observed the higher uptake of N, P, K and S with the application of 60 kg S ha^{-1} over no sulphur and 30 kg S ha^{-1}.

It is summarize from review narrated above that chickpea responded favourably to sulphur fertilizer in most of the soils. It is further revealed from the review that chickpea responded adequately to application of 40 to 60 kg S ha^{-1} in sandy loam and loamy sand soils, 40 kg S ha^{-1} in clayey and clay loam soils and 20 kg S ha^{-1} in calcareous alkaline soils. However, the optimum and economic dose varied in different agro-climatic regions.

Application of sulphur favourably influence the N, P and protein content in grain of chickpea.

MATERIALS AND METHODS

III. MATERIALS AND METHODS

The details of materials used, and the techniques adopted during the course of investigation are elaborated in this chapter.

3.1 EXPERIMENTAL SITE

The field experiment was conducted during *rabi* season of year 2002-03 at Regional Sugarcane Research Station, Gujarat Agricultural University, Thasra. Geographically, Thasra is situated at 22°-40′ North latitude and 73°-12′ East longitude with an elevation of 79.4 meter above the Mean sea level.

3.2 CLIMATE AND WEATHER

The climate of this region is semi-arid and sub-tropical. The summer is fairly dry and hot, while the winter is fairly cool and dry. The rainy season commences by the third week of June and retreats by end of September. The total rainfall recorded during 2002 was 788.00 mm, received in 26 rainy days and was less than average rainfall of 825.0 mm of this area. Timely and sufficiently rainfall in the monsoon is uncertain partial failure of rains once in three or four years is very common. July and August are the months of heavy precipitation. Practically, there is no rainfall in winter and summer seasons, almost in all parts of Gujarat state except sporadic showers in *Rabi* season. Temperature during rainy season varies from 23 to 35°C. However, in the month of October it rises as high as 38°C. It continues to drop from the beginning of November. Winter is moderate and usually sets during November and continues till the end of February. The lowest temperature is generally recorded in the months of January. Summer is hot and dry covering the months of April and May. The meteorological parameters for the period of investigation during 2002-2003 as recorded at the meteorological observatory of Trial-cum-demonstration farm, Thasra are presented in Table 3.1 and graphically depicted in Fig. 3.1.

Table: 3.1. Mean weekly weather parameters recorded during the crop season

Month/ Year	Std. Week	Date	Temperature, °C			Mean R.H. (%)	Sunshine (hrs.)	Evaporation, (mm)
			Max.	Min.	Mean			
October, 2002	40	1-7	37.7	33.6	35.6	66	10.33	5.17
	41	8-14	38.0	23.7	30.8	63	9.50	4.41
	42	15-21	36.6	23.0	29.8	70	9.70	4.80
	43	22-28	33.7	19.0	26.4	64	9.66	4.52
	44	29-4	34.4	19.6	27.0	58	9.46	4.13
November, 2002	45	5-11	33.9	18.7	26.3	72	8.07	4.12
	46	12-18	32.9	18.1	25.5	67	9.21	4.00
	47	19-25	33.3	16.4	24.8	59	9.79	4.30
	48	26-2	34.3	14.6	24.5	57	9.10	3.92
December, 2002	49	3-9	32.6	13.9	23.3	53	8.96	3.81
	50	10-16	32.1	13.3	22.7	60	9.37	4.00
	51	17-23	31.6	14.9	23.3	64	9.23	3.61
	52	24-31	28.0	12.7	20.4	63	9.00	4.10
January, 2003	1	1-7	25.3	11.6	18.5	57	8.66	3.98
	2	8-14	27.3	12.0	19.7	48	9.33	4.30
	3	15-21	28.3	11.6	19.9	47	9.01	4.37
	4	22-28	32.0	12.9	22.5	50	9.34	4.57
	5	29-4	32.7	17.0	24.8	70	9.67	3.67
February, 2003	6	5-11	32.6	21.4	27.0	67	9.27	4.27
	7	12-18	33.9	21.9	27.9	64	10.01	3.76
	8	19-25	29.1	16.4	22.7	66	10.17	4.26
	9	26-4	33.6	17.1	25.4	61	9.96	5.91
March, 2003	10	5-11	32.3	13.0	22.6	45	9.51	6.27
	11	12-18	34.7	16.0	25.4	54	5.83	7.87
	12	19-25	36.3	19.6	27.9	55	9.74	8.14
	13	26-1	39.6	19.7	29.6	51	10.23	9.74

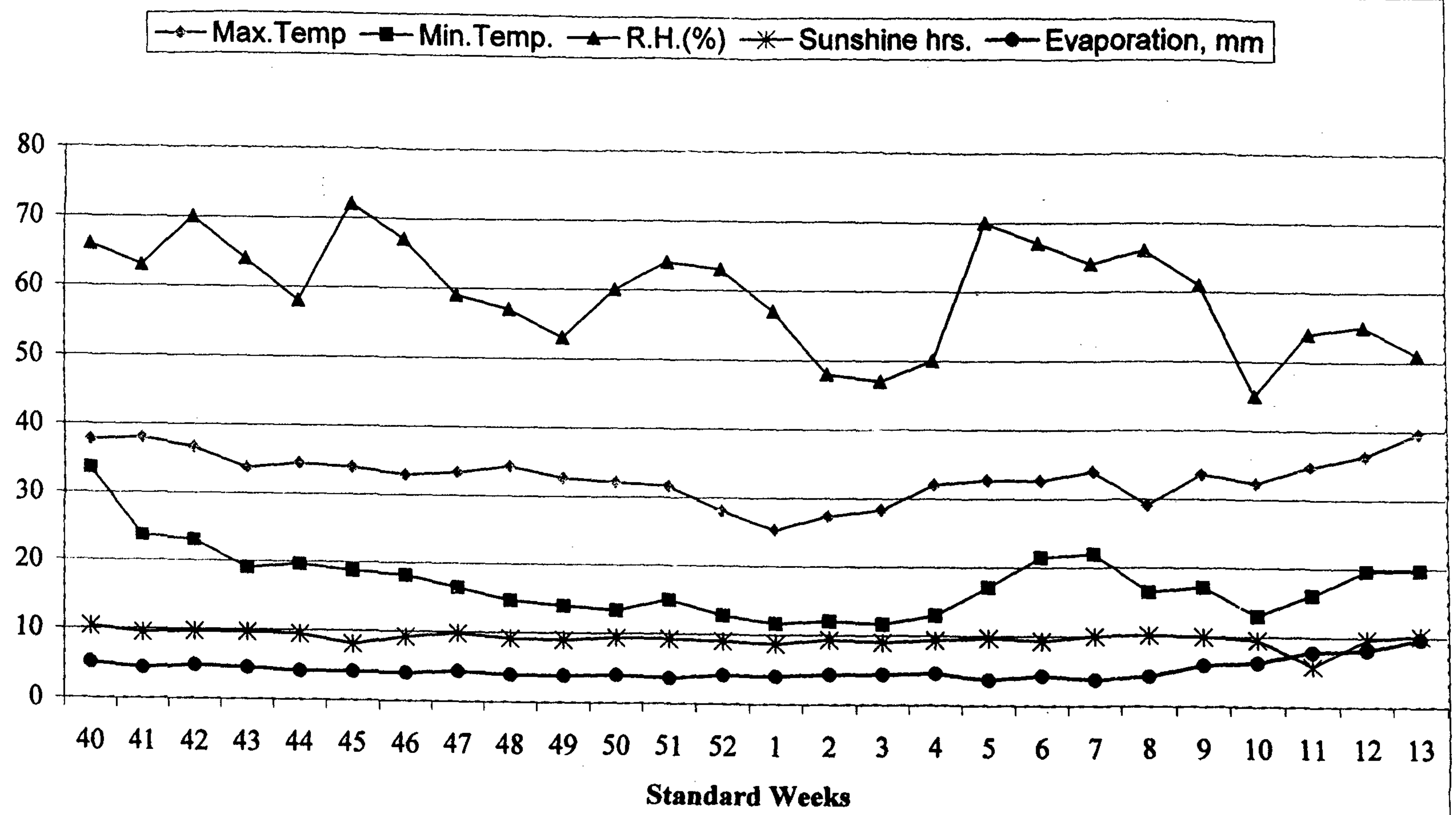

Fig. 3.1. Mean weekly weather parameters recorded during the crop season

The weekly mean maximum temperature varied from 25.30 to 39.6°C, while the weekly mean minimum temperature varied from 11.6 to 33.6°C during the crop season.

3.3. PHYSICO-CHEMICAL CHARACTERISTICS OF SOIL

The experimental field had an even topography with a gentle slope and good drainage. The texture of soil is sandy clay loam. The soil is very fairly moisture retentive. This soil responds well to manuring and irrigation. It is suitable for variety of crop of tropical and sub tropical regions. The ground water table being varies from 9.5 to 13.5 m depth. Hence, there is no problem of high water table in the area.

The physico-chemical properties of experimental plot were determined by drawing soil samples randomly before commencement of experiment from a depth of 0-15 cm and 15-30 cm and a composite sample was prepared and analyzed for physical and chemical properties of the soil. The values of soil analysis along with methods followed are furnished in Table 3.2.

It is evident from the data (Table 3.2) that the soil of experimental field was sandy clay loam in texture, low in organic carbon and nitrogen, medium in available phosphorus and high in available potassium.

Table 3.2. Physico-chemical properties of the experimental soil

Properties	Values at soil depth (cm) (0-15)	(15-30)	Method adopted
(A) Physical properties			
Coarse sand (%)	0.50	0.49	International pipette method
Fine sand (%)	65.00	66.20	(Piper- 1966)
Silt (%)	10.20	9.5	-------,, ----------
Clay (%)	24.20	23.20	-------,, -----------
Field capacity (%)	21.00	21.00	Actual field method (Dastane-1972)
Permanent wilting point (%)	6.50	6.50	Sunflower method (Dastane-1972)
Textural class	Sandy clay loam		
(B) Chemical properties			
Organic carbon (%)	0.37	0.38	Walkly and Black method (Jackson, 1973)
Total nitrogen (%)	0.032	0.033	Kjeldahl's method (Jackson, 1973)
Available P_2O_5(kg ha^{-1})	32.5	33.0	Olsen's method (Chopra and Kanwar, 1976)
Available K_2O (kg ha^{-1})	296	260	Flame photometric method (Jackson, 1973)
Available Sulphur (kg ha^{-1})	22.89	22.60	Turbid metric method (Chaudhary and Cornfield, 1966)
Soil pH (1:2.5, Soil: water ratio)	7.9	8.0	Buckman pH meter (Jackson, 1973)
Electric Conductivity (dsm^{-1} at 25° C)	0.35	0.38	Conductivity meter (Jackson, 1973)

3.4 CROPPING HISTORY OF EXPERIMENTAL PLOT

The detail regarding the cropping history in respect of crop grown and fertilizer applied to the experimental plot No- 'GHI' during the two years preceding, the present investigation is presented in Table 3.3.

Table 3.3. Cropping history of experimental plot

Year	Season	Crop	Fertilizer (kg ha^{-1})		
			N	P_2O_5	K_2O
2000-01	*Kharif*	Paddy	100	25	0
	Rabi	Gram	25	50	0
	Summer	Fallow	--	--	--
2001-02	*Kharif*	Paddy	100	25	0
	Rabi	Fallow	----	---	---
	Summer	Tomato	100	50	50
2002-03	*Kharif*	Paddy	100	25	0
	Rabi	Present	25	50	0
		Experiment of Chickpea	(FYM and S as per treatment)		

3.5 CROP AND VARIETY

The chickpea variety ICCC-4 was selected for the present investigation. This variety released by ICRISAT, Hyderabad in 1983. The details of this variety are presented as under.

Sr. No.	Characters	Description
1.	Plant height (cm)	42.5
2.	Maturity (days)	110 - 115
3.	Branches plant^{-1}	6.6
4.	Pods plant^{-1}	65
5.	Weight of 100 seeds (g)	14.1
6.	Seed size	Medium bold
7.	Seed colour	Yellowish brown
8.	Protein content (%)	23-24
9.	Grain yield (kg ha^{-1})	1995

3.6 EXPERIMENTAL DETAILS

The details of the experimental techniques employed for the investigation on "Influence of irrigation, FYM and sulphur on growth, yield and quality of chickpea (*Cicer arientinum* L.) are described here after.

3.6.1 Experimental treatments

The details of treatments are as under:

I Main plot treatments

(A) Irrigation levels (I)

(i) I_0- Pre-sowing irrigation (100 mm)

(ii) I_1- Pre-sowing irrigation + Irrigation at flowering stage (60 mm)

(B) Levels of Farmyard manure (F)

(i) F_0- 0 tone FYM ha^{-1}

(ii) F_1- 10 tones FYM ha^{-1}

II Sub plot treatments

(C) Levels of Sulphur (S)

(i) S_0 - 0 kg sulphur ha^{-1}

(ii) S_1 - 20 kg sulphur ha^{-1}

(iii) S_2 - 40 kg sulphur ha^{-1}

Thus, there were 12 treatment combinations given in Table 3.4.

3.6.2 Experimental design and lay out

Split plot design was employed in the present investigation with combination of two levels of irrigation and two levels of FYM in main plot and three levels of sulphur as sub plot treatments were adopted as shown in Fig- 3.2. Other details are as follows:

1. Number of replication			: Four (4)
2. Number of treatment combinations			: 12
3. Number of total plots			: 48
4. Plot size	(a) Gross		: 4.0 m × 2.4 m
	(b) Net		: 3.0 m × 1.2 m
5. Spacing			: 30 × 10 cm
6. Total number of rows plot^{-1}	(a) Gross		: 8
	(b) Net		: 4
7. Direction of sowing			: East- West
8. Seed rate			: 60 kg ha^{-1}
9. Crop and variety			: Chickpea, ICCC-4
10. Season			: *Rabi* 2002-03
11. Fertilizer			: 25: 50: 0, N P K, kg ha^{-1}

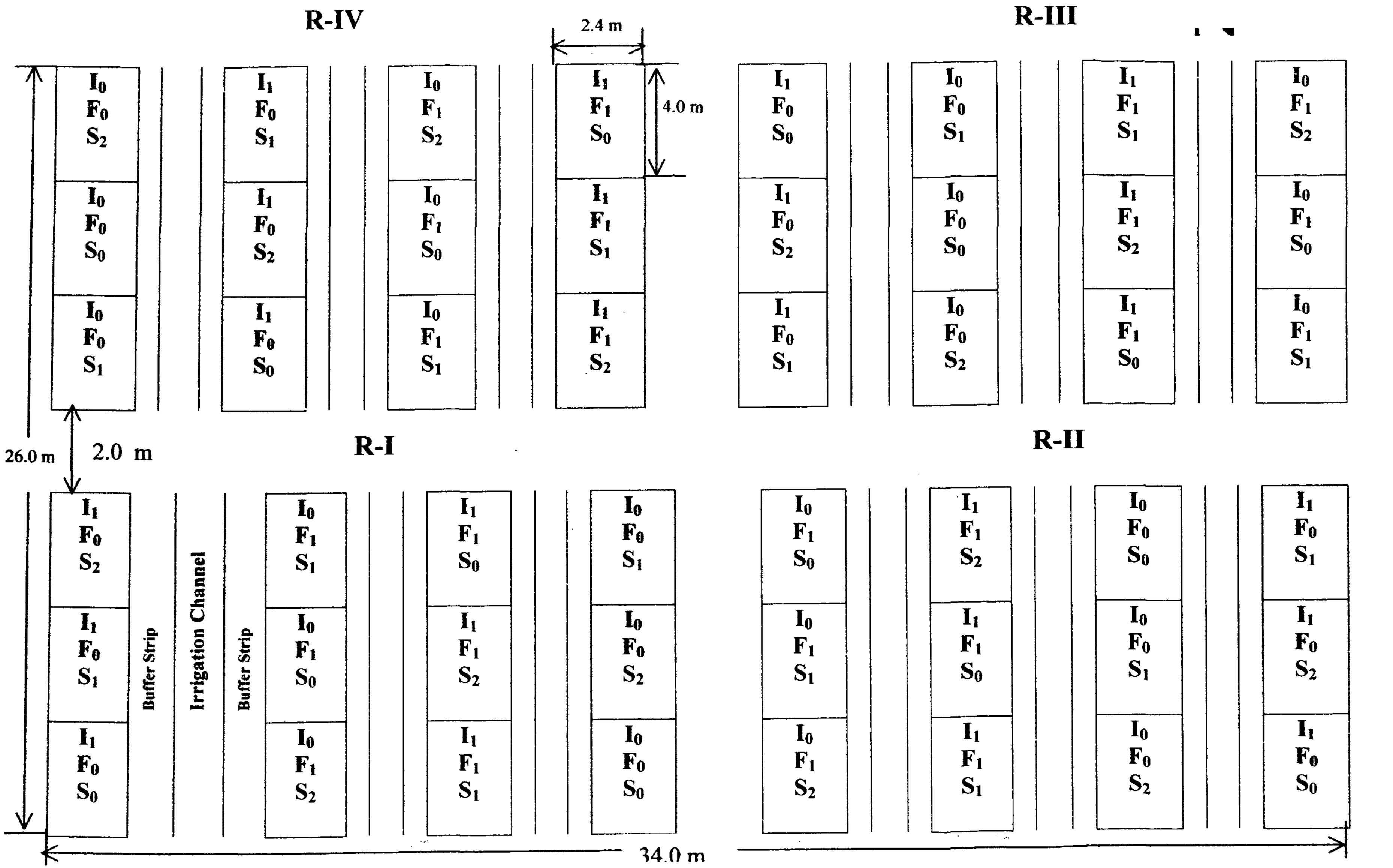

Fig. 3.2. : Lay out plan of experimental site

Plot size: Gross: 4.0 m × 2.4 m
Net: 3.0 m × 1.2 m
Design: Split plot

Table 3.4. **Details of treatment combinations**

Sr. No.	Treatment Symbol	Treatment combination: Irrigation schedule	FYM	Sulphur
1.	$I_0F_0S_0$	Pre-sowing irrigation	0 tonne ha^{-1}	0 kg ha^{-1}
2.	$I_0F_0S_1$	Pre-sowing irrigation	0 tonne ha^{-1}	20 kg ha^{-1}
3.	$I_0F_0S_2$	Pre-sowing irrigation	0 tonne ha^{-1}	40 kg ha^{-1}
4.	$I_0F_1S_0$	Pre-sowing irrigation	10 tonne ha^{-1}	0 kg ha^{-1}
5.	$I_0F_1S_1$	Pre-sowing irrigation	10 tonne ha^{-1}	20 kg ha^{-1}
6.	$I_0F_1S_2$	Pre-sowing irrigation	10 tonne ha^{-1}	40 kg ha^{-1}
7.	$I_1F_0S_0$	Pre-sowing irrigation + Irrigation at flowering stage	0 tonne ha^{-1}	0 kg ha^{-1}
8.	$I_1F_0S_1$	Pre-sowing irrigation + Irrigation at flowering stage	0 tonne ha^{-1}	20 kg ha^{-1}
9.	$I_1F_0S_2$	Pre-sowing irrigation + Irrigation at flowering stage	0 tonne ha^{-1}	40 kg ha^{-1}
10.	$I_1F_1S_0$	Pre-sowing irrigation + Irrigation at flowering stage	10 tonne ha^{-1}	0 kg ha^{-1}
11.	$I_1F_1S_1$	Pre-sowing irrigation + Irrigation at flowering stage	10 tonne ha^{-1}	20 kg ha^{-1}
12.	$I_1F_1S_2$	Pre-sowing irrigation + Irrigation at flowering stage	10 tonne ha^{-1}	40 kg ha^{-1}

3.7 CULTURAL OPERATIONS

A schedule of cultural operations followed during entire crop season is presented in Table 3.5.

3.7.1 Preparation of land

The experimental field was cross-cultivated by tractor drawn cultivator. Stubbles of previous crop were collected and removed from the field. Planking was done in both the direction to develop a fine tilth. The layout of experiment was done as per design employed.

3.7.2 Fertilizer application

Furrows were opened manually in each plot keeping spacing of 30 cm in between two rows. Required quantity of nitrogen and phosphorus, FYM and sulphur were weighed separately for each treatment and were placed in the respective plots about 5 to 6 cm deep, just prior to sowing in the previously opened furrows and the furrows were slightly covered with the soil. A basal dose of nitrogen @ 25 kg ha^{-1} was applied to all the plots. Nitrogen was applied in the form of urea, whereas phosphorus and sulphur were applied in the form of diammonium phosphate and gypsum, respectively.

3.7.3 Seed and sowing

Certified seeds of chickpea ICCC-4 were used for sowing. The seeds were sown manually 3-4 cm deep in the previously opened furrows keeping inter row with a recommended seed rate of 60 kg ha^{-1}.

Table-3.5. Calendar of operations carried out during the experimental period

Sr. No.	Cultural operations	Frequency	Date
(A)	**Pre-sowing operations**		
1.	Tractor cultivation (cross wise)	1	20-10-2002
2.	Pre-sowing irrigation as per treatment	1	25-10-2002
3.	Tractor cultivation (cross wise)	1	30-10-2002
4.	Field lay out	1	30-10-2002
5.	Opening of furrows	1	31-10-2002
6.	Application of FYM and sulphur i.e. Gypsum as per treatment	1	31-10-2002
7.	Application of N, P_2O_5 as basal dose	1	31-10-2002
8.	Preparation of beds and irrigation channels	1	1-11-2002
(B)	**Sowing and post-sowing operations**		
1.	Sowing of seed in furrow by hand	1	31-10-2002
2.	Gap filling and thinning	1	7-11-2002
3.	Interculturing	1	1-12-2002
4.	Weeding	2	17-11-2002 17-12-2002
5.	Irrigation at flowering as per treatment		21-12-2002
6.	Plant protection (Spraying of Endosulphan 0.07%)	1	05-02-2003
7.	Harvesting		
	I_0 treatment	1	01-03-2003
	I_1 treatment	1	07-03-2003
8.	Threshing and winnowing		
	I_0 treatment	1	08-03-2003
	I_1 treatment	1	16-03-2003

3.7.4 Irrigation

One pre-sowing irrigation of 100 mm depth was given before the layout was done and later on one irrigation was given at flowering stage as per treatment. The quantity of irrigation water was measured with 7.5 cm cut throat parshal flume installed under free flow conditions. Depth of 60 mm water was applied in irrigation given at flowering stage.

3.7.5 Post sowing operations

After the complete germination of crop seed, gap filling and thinning operations were carried out for maintaining uniform plant stand.

Two hand weedings and one interculturing were done during the early crop growth stage. One spray of 0.07% Endosulphan was done for the control of pod borer.

3.7.6 Harvesting and threshing

After the maturity of the crop, randomly selected plants (previously tagged) from each net plot were first harvested for recording necessary biometric observations and produce was added to respective net plot later on. The borderlines were harvested first and were removed out of the experimental plots. Then, net area was harvested separately and left for sun drying in respective plots. After complete drying, the harvested produce was weighed just before threshing to record biological yield. Thereafter, threshing was done with the help of hand operated thresher, seeds per plot thus collected were winnowed, cleaned and weighed. The crop was harvested on 1st March, 2003 and 7th March for I_0 and I_1 treatments, respectively.

3.8 BIOMETRIC OBSERVATIONS

The biometric observations were recorded from five randomly selected plants tagged within each net plot. The detail of various growth parameters, yield attributes, quality and chemical parameters studied during the course of investigation given in Table 3.6. Details of the techniques followed for recording the observations are also described accordingly.

Table 3.6. Parameters studied during the course of investigations

Sr. No.	Characters	Sample size	Time of recording
1.	**Plant population**	3 samples of one meter row length in each net plot	At harvest
2.	**Growth parameters**		
	(i) Plant height (cm)	Five plants net plot^{-1}	30, 60 DAS and at harvest
	(ii) Number of branches per plant	- " -	At harvest
	(iii) Number of nodules per plant	-" -	At 45 DAS
	(iv) Dry weight of nodules per plant (mg)	- " -	At 45 DAS
3.	**Yield and yield attributes**		
	(i) Number of pods per plant	-"-	At harvest
	(ii) Grain yield per plant(g)	- " -	At harvest
	(iii) Grain yield (kg ha^{-1})	As described in procedure	At harvest
	(iv) Straw yield (kg ha^{-1})	As described in procedure	At harvest
	(v) Test weight (g)	As described in procedure	At harvest
	(vi) Harvest index (%)	As described in procedure	At harvest
4.	**Biochemical parameters**		
	(i)Nitrogen content in grain (%)	Sample from each net plot	At harvest
	(ii) Protein content in grain (%)	As described in procedure	At harvest
	(iii)Sulphur content in grain (%)	Sample from each net plot	At harvest
5.	Soil moisture measurement (%)	As described in procedure	At flowering 50 DAS) and pod development stages (90 DAS)
6.	Post Harvest available nutrients (N, P, K and S kg ha^{-1})	Soil sample from each net plot	At harvest

3.8.1 Plant Population

Plant population at harvest was recorded by counting the number of plants with taking 3 samples of one meter row length in each net plot and converted to hectare basis.

3.8.2 Growth parameters

3.8.2.1 Plant height (cm)

Plant height was recorded at 30, 60 DAS and at harvest for five randomly selected plants in each net plot and average was calculated and recorded separately. The selected plants were also used for other observations (harvesting observations).

3.8.2.2 Number of branches per plant

All the effective branches from the selected five plants in each plot and average value for each plot were worked out and recorded.

3.8.2.3 Number of nodules per plant

Observation of number of nodules per plant was taken on 45th days after sowing. Five plants from each net plot were randomly selected for this purpose. The plants were dug out with the help of *kudali*. Sufficient care was taken, so that entire root system of the plants could be removed from the soil without any injury to nodules. Root portion of plant was kept in water filled in a bucket to wash out soil particles from the root portion. There after, individual nodules were separated from the root portion and counted for each plot. The average numbers of nodules per plant were recorded treatment wise.

3.8.2.4 Dry weight of nodules per plant (mg)

After counting effective nodules per plant, these nodules were first air dried and later dried in an oven at 70 °C till constant weight was obtained and average value of dry nodules weight for each treatment was worked out and recorded.

3.8.3 Yield and yield attributes

3.8.3.1 Number of pods per plant

The total number of developed pods from previously five tagged plants at the time of harvest was counted and their average value per plant was worked out and recorded for each treatment.

3.8.3.2 Grain yield per plant (g)

The previously tagged five plants were used for working out the mean seed yield in gramme per plant at harvest. Lateron, it was added to seed yield of net plot.

3.8.3.3 Grain yield (kg ha^{-1})

The produce of each net plot area was threshed separately, cleaned and the grain yield recorded per plot was then computed on hectare basis.

3.8.3.4 Straw yield (kg ha^{-1})

The plot wise straw yield was obtained by deducting the grain yield from the total produce (dry biomass) and recorded in kg $plot^{-1}$. The straw yield was inclusive of stem, leaves, and pod husk, straw yield then computed on hectare basis.

3.8.3.5 Test weight (g)

A representative grain sample was drawn randomly from the bulk the produce of each net plot, one thousand grains were counted from the sample, and their weight in gramme was recorded as test weight for each treatment.

3.8.3.5 Harvest index (%)

Harvest index is the ratio of economic yield to the biological yield per plot .It was calculated by using following formula, (Donald and Hamblin, 1976).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Above ground biological yield (kg ha}^{-1}\text{)}} \times 100$$

3.9 BIOCHEMICAL STUDIES

3.9.1 Nitrogen content in seeds

The seed samples from four replications were analyzed for total N content.

Representative samples of seeds were drawn from each net plot yield and oven dried at 70 °C till a constant weight was obtained. The oven dried samples were ground in a willy Mill fixed with 60 mesh sieve and then used for biochemical analysis. The technique employed for the biochemical analysis of nitrogen constituents was micro-Kjeldahl digestion and distillation method (Jackson, 1973).

3.9.2 Protein content in seeds

The protein content in seeds was calculated by multiplying nitrogen content of seeds (%) with the conversion factor of 6.25 as reported by Gupta *et al.* (1972).

3.9.3 Sulphur content in seeds

The technique employed for the biochemical analysis of sulphur constitutions was Turbid metric method (Chaudhary and Cornfield, 1966).

3.9.4 Post harvest available nutriments in soil

Representative samples of soil were drawn from each plot after harvest of crop and composite samples were prepared for chemical analysis. The details of techniques followed for the chemical analysis for estimation of N,P_20_5, K_20, and S of soil are presented in Table 3.6.

Table 3.7. Techniques adopted in chemical analysis

Sr. No.	Estimation of constituents	Method adopted
1.	Nitrogen content in soil	Micro-Kjeldahl's digestion and distillation method (Jackson, 1973)
2.	Phosphorus content in soil.	Vanodomolybdo phosphoric acid yellow colour method in nitric acid system.
3.	Potassium content in soil.	Flame photometric method (Jackson, 1973)
4.	Sulphur content in soil.	Turbid metric method (Chaudhary and Cornfield, 1966).

3.10 Soil moisture content

Moisture content in soil was measured at the time of flowering (before irrigation in respective treatment, 50 DAS) and at pod development stage (90 DAS). Soil samples are taken from 15 cm depths in each net plot of the experiment. The empty sampler are weighed first and then the soil samples are weighed with sampler box, dried in an oven at 105 °C for 24 hours and then weighed again, the difference in weight is the amount of moisture in the soil usually expressed as percentage on dry weight basis, it is calculate by formula given below:

$$\text{Moisture Content (\%)} = \frac{(W_1-W_3)-(W_2-W_3)}{(W_2-W_3)}$$

Where W_1= Weight of wet soil with sample box (gm)

W_2 = Weight of dry soil with sample box (gm)

W_3 = Weight of sample box (gm).

3.11 ECONOMICS

In order to evaluate the effectiveness of each individual treatment, the relative economics of each treatment combination was worked out in terms of net profit, so that the most effective and remunerative treatment combination could be found out. The gross realization in terms of rupees per hectare was calculated from the realization received from grain and straw yields at the prevailing market price during the course of investigation. The cost of cultivation was worked out considering the cost of all operations right from the cost of preparation of land to the harvesting of the crop and the cost of all inputs involved. The net realization was worked out by deducting the total cost of cultivation from the gross realization per hectare for each treatment combinations and record accordingly. The CBR was calculated on the basis of formula given below:

$$CBR = \frac{\text{Total income (Rs)}}{\text{Total expenditure (Rs)}}$$

3.12 STATICAL ANALYSIS

A statistical analysis of the data of various characters studied in the investigation was carried out through the statistical analysis of variance technique as described by Panse and Sukhatme (1967) by the computer system at the computer centre, B.A.College of Agriculture, Anand. The significance of differences was tested by 'F' test. Five per cent level of significance was used to test the significant of results. The critical differences were calculated when differences among the treatments were found significant by 'F' test. In remaining cases only standard error of mean was worked out. The co-efficient of variation (C.V. %) was also worked out.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The results obtained in the present investigation entitled "Influence of irrigation, FYM and sulphur on growth, yield and quality of chickpea under middle Gujarat conditions" conducted at Regional Sugarcane Research Station, Gujarat Agricultural University, Thasra during *rabi* season of the year 2002-03. The data pertaining to various growth and yield attributes, grain yield and its quality and economics have been presented in the tables and also illustrated graphically wherever necessary in this chapter along with statistical inferences. The summary of analysis of variance of these parameters is also presented in Appendix-I.

The data for all main effects and only significant interactions are presented in suitable tables and discussed in the write up.

4.1. GROWTH PARAMETERS

4.1.1. Plant population

Data regarding the plant population recorded at harvest presented in Table 4.1.

4.1.1.1. Effect of Irrigation, FYM and Sulphur

A perusal of data given in Table 4.1 revealed that different levels of irrigation, FYM and sulphur did not show significant influence on plant population. This indicates a uniform plant stand under all the treatments.

4.1.1.2. Interaction effect

An interaction effect was absent.

Table: 4.1. Plant population of chickpea as influenced by different levels of irrigation, FYM and sulphur treatments

Treatment	Plant population at harvest
Irrigation (I)	
I_0- Pre-sowing irrigation	10.60
I_1- Pre-sowing irrigation + at flowering stage	11.00
S.Em. ±	0.20
C.D. (P= 0.05)	NS
FYM (F)	
F_0- 0 tone FYM ha^{-1}	10.60
F_1- 10 tone FYM ha^{-1}	11.00
S.Em. ±	0.20
C.D. (P= 0.05)	NS
C.V. %	8.95
Sulphur (S)	
S_0- 0 kg sulphur ha^{-1}	10.77
S_1-20 kg sulphur ha^{-1}	10.79
S_2-40 kg sulphur ha^{-1}	10.83
S.Em. ±	0.28
C.D. (P= 0.05)	NS
C.V. %	10.21
Sig. Interaction	NS

4.1.2. Plant height (cm)

Data on periodical plant height as influenced by different levels of irrigation, FYM and sulphur are presented in Table 4.2 and graphically depicted in Fig. 4.1.

4.1.2.1. Effect of irrigation

Data given in Table 4.2 revealed that the plant height was significantly influenced by different levels of irrigation at all the growth stages except at 30 DAS, wherein the differences due to irrigation were non significant. Significant differences in plant height were noticed at 60 DAS and at harvest. In both cases I_1 showed its significant superiority in increasing the plant height over I_0.

4.1.2.2. Effect of FYM

The results indicated that FYM application significantly improved the plant height only at 60 DAS, wherein F_1 had significantly increased the plant height over F_0. However, at 30 DAS and at harvest though the FYM application had numerically increased the plant height, it failed to reach to a level of significance.

4.1.2.3. Effect of sulphur

Statistical analysis of data (Table 4.2) further revealed that plant height was significantly influenced by sulphur levels only at 60 DAS. The graded doses of sulphur increased the plant height significantly at each level of applied sulphur and the tallest plant was noted with S_2.

4.1.2.4. Interaction effect

Among different interactions, I × F was found significant only at 60 DAS for plant height. The data are presented in Table 4.3.

Table: 4.2. Plant height 30, 60 DAS and at harvest of the crop as influenced by different levels of irrigation, FYM and sulphur treatments

Treatment	Plant height (cm) (30 DAS)	Plant height (cm) (60 DAS)	Plant height (cm) at harvest
Irrigation (I)			
I_0- Pre-sowing irrigation	14.72	27.86	44.75
I_1- Pre-sowing irrigation + at flowering stage	14.58	34.03	46.53
S.Em. ±	0.25	0.16	0.48
C.D. (P= 0.05)	NS	0.50	1.52
FYM (F)			
F_0- 0 tone FYM ha^{-1}	14.31	30.06	45.07
F_1- 10 tone FYM ha^{-1}	15.00	31.80	46.22
S.Em. ±	0.25	0.16	0.48
C.D. (P= 0.05)	NS	0.50	NS
C.V. %	8.30	2.50	5.12
Sulphur (S)			
S_0- 0 kg sulphur ha^{-1}	14.45	29.16	45.14
S_1-20 kg sulphur ha^{-1}	14.55	30.78	45.96
S_2-40 kg sulphur ha^{-1}	14.95	32.85	45.84
S.Em. ±	0.25	0.25	0.69
C.D. (P= 0.05)	NS	0.72	NS
C.V. %	6.87	3.17	6.02
Sig. Interaction	NS	I × F	NS

Table: 4.3. Plant height (60 DAS) as influenced by I × F interaction

Treatment	FYM (F)	
Irrigation (I)	F_0	F_1
I_0	27.37	28.28
I_1	32.75	35.32
S.Em. ±	0.22	
C.D. (P= 0.05)	0.71	
C.V. %	2.50	

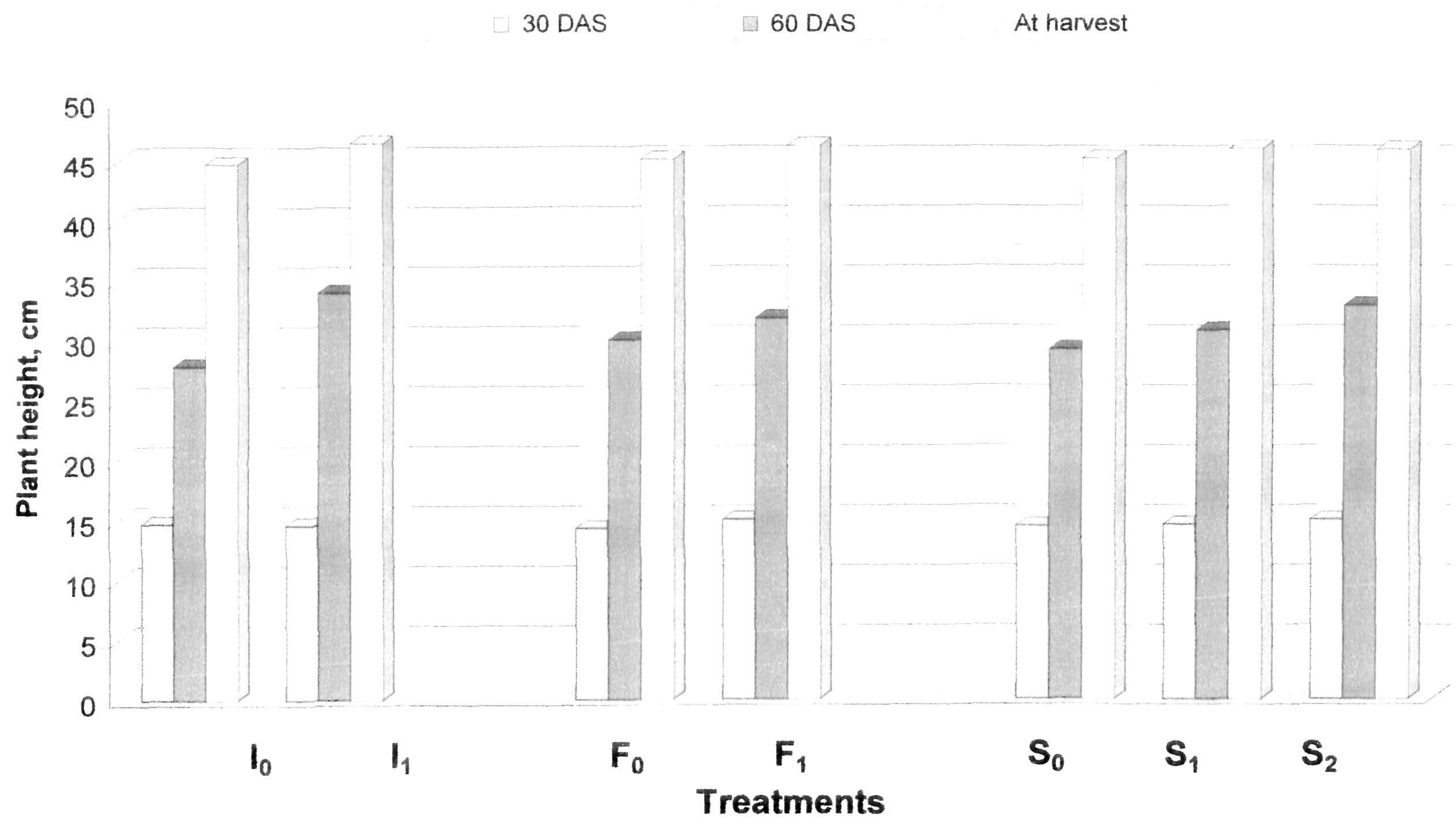

Fig. 4.1. Plant height as influenced by different levels of irrigation, FYM and sulphur

An examination of data revealed that the treatment combination I_1F_1 produced significantly taller plants (35.32 cm) as compared to rest of the all treatment combinations. Significantly the lowest plant height (27.37 cm) was recorded with I_0F_0. It is interesting to note that plant height was significantly increased due to FYM not only in presence of post sowing irrigation but also in absence of this irrigation.

4.1.3. Number of branches per plant

Data regarding the number of branches per plant recorded at harvest as influenced by different levels of irrigation, FYM and sulphur are presented in Table 4.4.

4.1.3.1. Effect of irrigation

It was observed from the data (Table 4.4) that the differences in number of branches per plant were found significant due to irrigation schedule. Irrigation (I_1) applied at pre and post sowing (at flowering) produced significantly more number of branches per plant than irrigation applied only at the time of sowing (I_0).

4.1.3.2. Effect of FYM

The significant variation in number of branches per plant was observed with FYM application (Table 4.4). Application of FYM @ 10 tonnes ha^{-1} (F_1) produced significantly higher number of branches per plant than no FYM (F_0).

4.1.3.3. Effect of sulphur

The differences in number of branches per plant due to varying levels of sulphur were found significant. The S_1 and S_2 being at par significantly increased the number of branches per plant over S_0. The maximum number of branches per plant was recorded with S_2 and the minimum with S_0.

Table: 4.4. Number of branches per plant as influenced by different levels of irrigation, FYM and sulphur treatments

Treatment	Number of branches per plant
Irrigation (I)	
I_0- Pre-sowing irrigation	5.28
I_1- Pre-sowing irrigation + at flowering stage	5.94
S.Em. ±	0.20
C.D. (P= 0.05)	0.63
FYM (F)	
F_0- 0 tone FYM ha^{-1}	5.21
F_1- 10 tone FYM ha^{-1}	6.02
S.Em. ±	0.20
C.D. (P= 0.05)	0.63
C.V. %	17.15
Sulphur (S)	
S_0- 0 kg sulphur ha^{-1}	4.95
S_1-20 kg sulphur ha^{-1}	5.79
S_2-40 kg sulphur ha^{-1}	6.10
S.Em. ±	0.24
C.D. (P= 0.05)	0.70
C.V. %	17.08
Sig. Interaction	NS

4.1.3.4. Interaction effect

Data presented in Table 4.4 revealed that interactions effect were found to be non-significant with respect to number of branches per plant.

4.1.4. Number of nodules per plant

Data pertaining to number of nodules per plant as affected by various levels of irrigation, FYM and sulphur treatments are presented in Table 4.5 and graphically depicted in Fig. 4.2.

4.1.4.1. Effect of irrigation

A perusal of data given in Table 4.5 indicate that number of nodules per plant were significantly influenced by irrigation schedule wherein higher number of nodules per plant was found in I_1 treatment (44.13) than I_0 treatment (36.33).

4.1.4.2. Effect of FYM

A close examination of data (Table 4.5) revealed that the difference in number of nodules per plant between two levels of FYM was significant. Application of FYM (10 tonnes ha^{-1}) produced significantly higher number of nodules per plant than no FYM (F_0).

4.1.4.3. Effect of sulphur

It is clear from the data (Table 4.5) that there were significant differences in number of nodules per plant among different sulphur levels. It was further noticed that the number of nodules per plant was increased significantly with each successive increase in the levels of sulphur. The lowest nodules per plant was recorded in absence of sulphur (S_0).

Table: 4.5. Number of nodules per plant and dry weight of nodules as influenced by different levels of irrigation, FYM and sulphur treatments

Treatment	Number of nodules per plant	Dry weight of nodules (mg)
Irrigation (I)		
I_0- Pre-sowing irrigation	36.33	264.40
I_1- Pre-sowing irrigation + at flowering stage	44.13	360.03
S.Em. ±	0.34	3.60
C.D. (P= 0.05)	1.10	11.52
FYM (F)		
F_0- 0 tone FYM ha^{-1}	39.08	301.39
F_1- 10 tone FYM ha^{-1}	41.38	323.04
S.Em. ±	0.34	3.60
C.D. (P= 0.05)	1.10	11.52
C.V. %	4.17	5.65
Sulphur (S)		
S_0- 0 kg sulphur ha^{-1}	37.94	259.40
S_1-20 kg sulphur ha^{-1}	40.19	309.59
S_2-40 kg sulphur ha^{-1}	42.56	367.65
S.Em. ±	0.20	2.90
C.D. (P= 0.05)	0.60	8.48
C.V. %	2.03	3.72
Sig. Interaction	I × F	NS

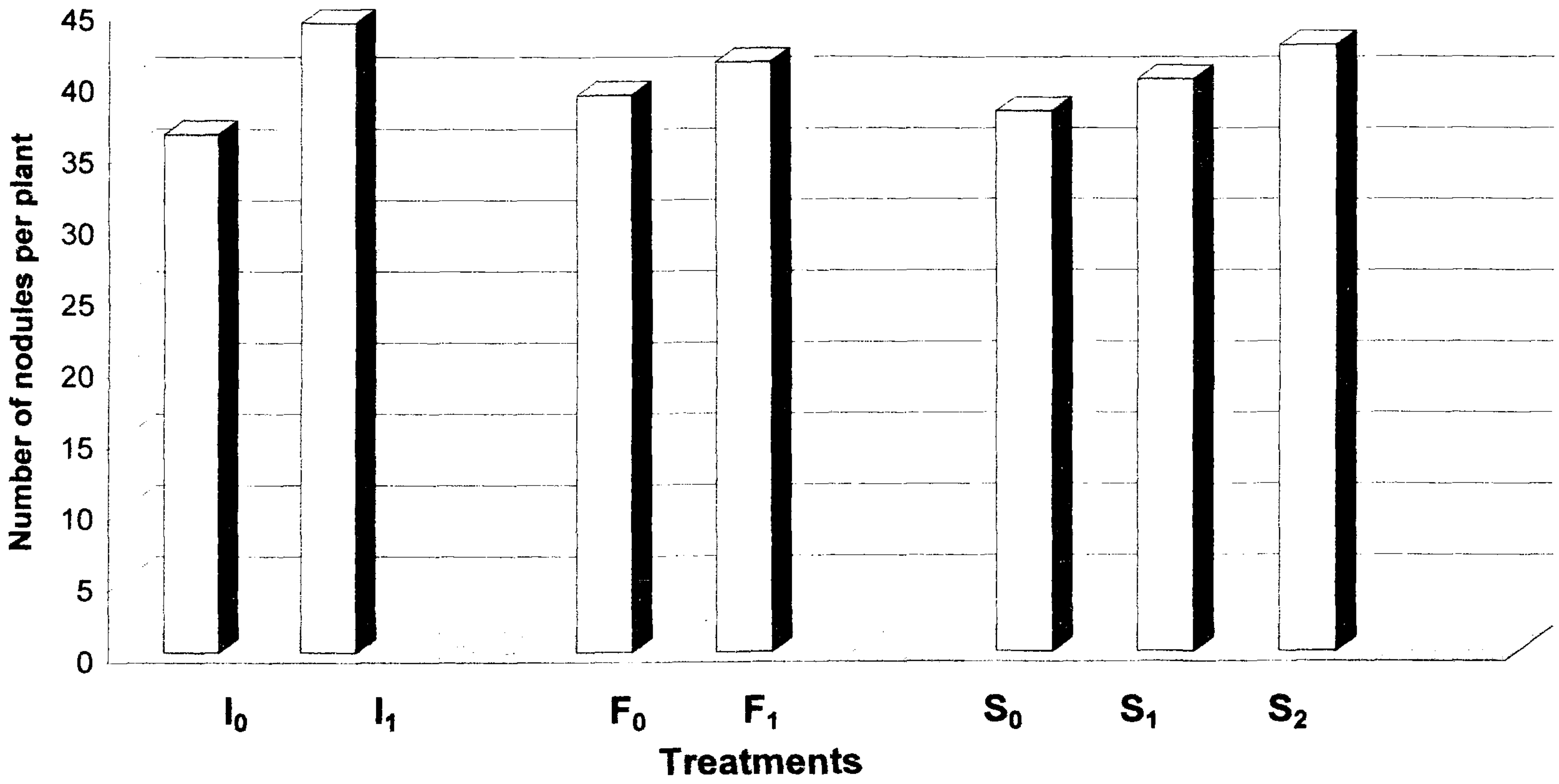

Fig. 4.2. Number of nodules per plant as influenced by different levels of irrigation, FYM and sulphur

4.1.4.4. Interaction effects

Interaction, irrigation × FYM was found significant in respect of number of nodules per plant (Table 4.6). Treatment combination I_1F_1 recorded significantly higher number of nodules per plant (45.83) as compare to rest of the treatment combinations. The I_0F_0 combination recorded the lowest value of nodules. Here it is interesting to note that in presence of pre and post sowing irrigation (I_1), F_1 gave significantly higher number of nodules than F_0. Whereas, both were at par in the irrigation schedule where pre and post-sowing irrigation (I_1) was absent.

Table: 4.6. Number of nodules per plant as influenced by I × F interaction

Treatment	FYM (F)	
Irrigation (I)	F_0	F_1
I_0	35.75	36.92
I_1	42.42	45.83
S.Em. ±	0.48	
C.D. (P= 0.05)	1.55	
C.V. %	4.17	

4.1.5. Dry weight of nodules per plant (mg)

The mean data pertaining to dry weight (mg) of nodules per plant as influenced by varying levels of irrigation, FYM and sulphur are presented in Table 4.5 and graphically depicted in Fig. 4.3

4.1.5.1. Effect of irrigation

Irrigation schedule had significant influence on dry weight of nodules. The I_1 irrigation schedule registered significantly higher dry weight of nodules per plant as compared to I_0.

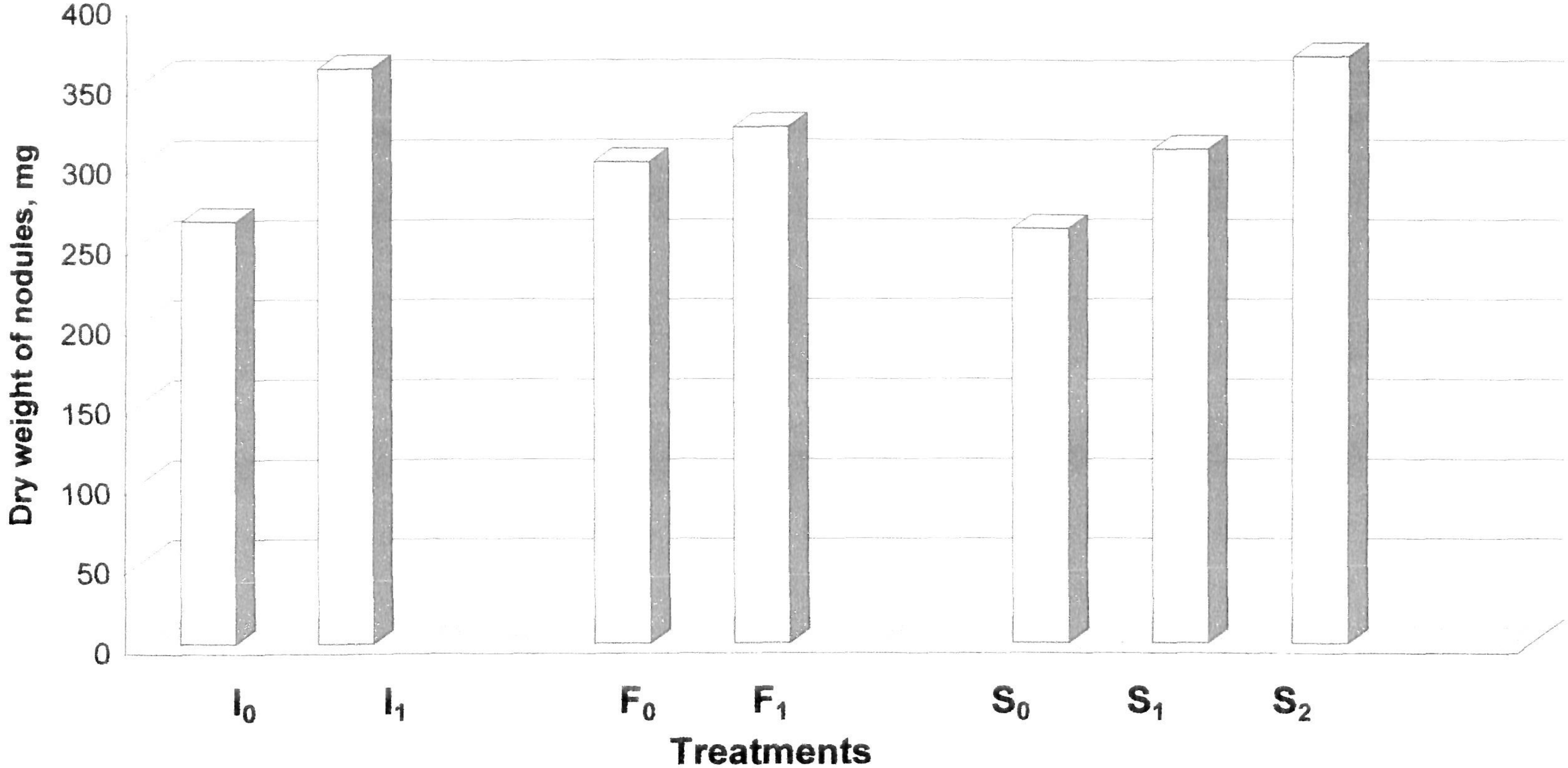

Fig. 4.3. Dry weight of nodules per plant as influenced by different levels of irrigation, FYM and sulphur

4.1.5.2. Effect of FYM

A significant variation in dry weight of nodules (mg) per plant was observed due to FYM application. The F_1 significantly recorded higher dry weight of nodules than F_0.

4.1.5.3. Effect of sulphur

It is apparent from the data (Table 4.5) that all the three levels of sulphur differed significantly from each other with respect to dry weight of nodules (mg) per plant and the response was linear. Significantly the highest dry weight was recorded with the sulphur level consisted highest dose of sulphur (S_2) and the lowest with lowest dose of sulphur (S_0). The dry weight of nodules was 259.40, 309.59 and 367.65 with S_0, S_1, and S_2, respectively.

4.1.5.4 Interaction effects

The effect of all possible interactions of various treatments were non significant.

4.2. YIELD AND YIELD ATTRIBUTES

4.2.1. Number of pods per plant

The mean data on number of pods per plant at harvest as influenced by different levels of irrigation, FYM and sulphur are presented in Table 4.7.

4.2.1.1. Effect of irrigation

It was observed from the results presented in Table 4.7 that number of pods per plant was significantly influenced by irrigation treatments. Treatment I_1 produced significantly the more number of pods per plant (85.74) over I_0 treatment with 68.89 pods per plant.

Table: 4.7. Number of pods per plant and grain yield per plant as influenced by different levels of irrigation, FYM and sulphur treatments

Treatment	Number of pods per plant	Grain yield per plant (g)
Irrigation (I)		
I_0- Pre-sowing irrigation	68.89	11.68
I_1- Pre-sowing irrigation + at flowering stage	85.74	15.33
S.Em. ±	2.97	0.65
C.D. (P= 0.05)	9.50	2.09
FYM (F)		
F_0- 0 tone FYM ha^{-1}	70.93	12.06
F_1- 10 tone FYM ha^{-1}	83.70	14.95
S.Em. ±	2.97	0.65
C.D. (P= 0.05)	9.50	2.09
C.V. %	18.82	23.70
Sulphur (S)		
S_0- 0 kg sulphur ha^{-1}	71.07	11.79
S_1-20 kg sulphur ha^{-1}	78.26	14.13
S_2-40 kg sulphur ha^{-1}	82.61	14.60
S.Em. ±	3.14	0.62
C.D. (P= 0.05)	9.17	1.80
C.V. %	16.25	18.29
Sig. Interaction	NS	NS

4.2.1.2 Effect of FYM

Number of pods per plant was significantly increased with FYM application. Treatment F_1 (10 t FYM ha^{-1}) showed its significant superiority in increasing number of pods per plant over F_0.

4.2.1.3. Effect of sulphur

Numbers of pods per plant recorded at harvest, significantly influenced by different levels of sulphur (Table 4.7). From the results, it was observed that significantly the highest number of pods per plant (82.61) was produced with the application of S_2 (40 kg S ha^{-1}), which was at par with S_1 (20 kg S ha^{-1}), while significantly the lowest number of pods per plant (71.07) was recorded under S_0 (0 kg S ha^{-1}).

4.2.1.4. Interaction effects

Data given in Table 4.7 indicated that there were no any interactions effect was found significant with respect to number of pods per plant.

4.2.2. Grain yield per plant (g)

Data on grain yield per plant as influenced by different levels of irrigation, FYM and sulphur treatments are presented in Table 4.7 and graphically illustrated in Fig. 4.4.

4.2.2.1. Effect of irrigation

Data given in Table 4.7 reveal that different levels of irrigation significantly influenced the grain yield per plant. Irrigation applied at pre

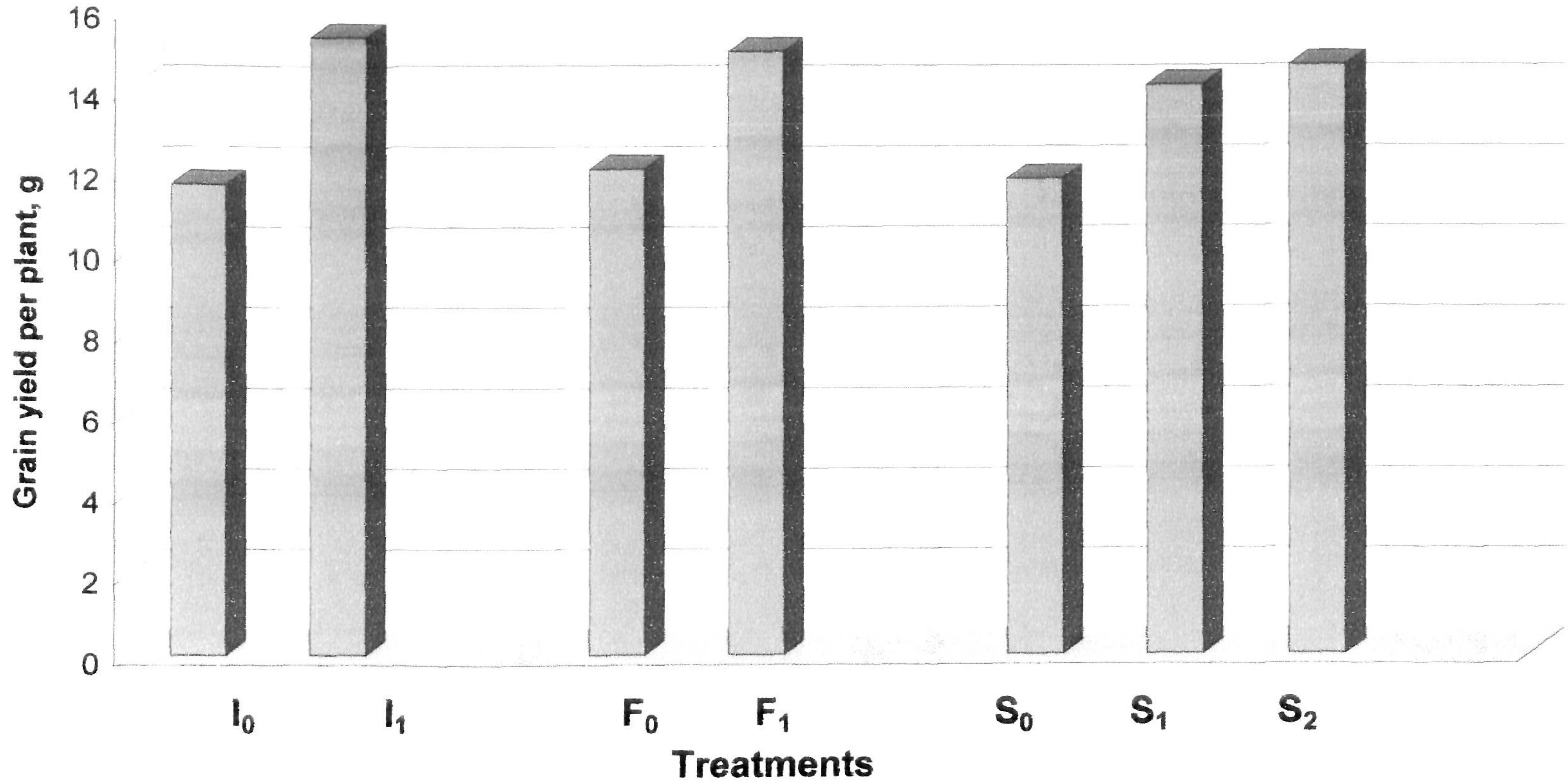

Fig. 4.4. Grain yield per plant as influenced by different levels of irrigation, FYM and sulphur

sowing and at flowering stage (I_1) produces significantly the higher grain yield per plant (15.33) as compare to irrigation applied only at the time of sowing (I_0).

4.2.2.2. Effect of FYM

Grain yield per plant was significantly increased with FYM application. Treatment F_1 (10 tonnes FYM ha^{-1}) recorded significantly the higher grain yield per plant (14.95) as compare to no application of FYM (12.06).

4.2.2.3. Effect of sulphur

The effect of sulphur on grain yield per plant (Table 4.7) was found significant. The results further indicated that sulphur levels S_1 and S_2 remained at par, but both had significantly increased the grain yield per plant over S_0. Significantly the lowest value was noted with S_0.

4.2.2.4 Interaction effects

Grain yield per plant did not affect due to different interactions effect.

4.2.3. Grain yield (kg ha^{-1})

Data pertaining to grain yield of chickpea as influenced by different treatments are presented in Table 4.8 and results are also graphically depicted in Fig. 4.5.

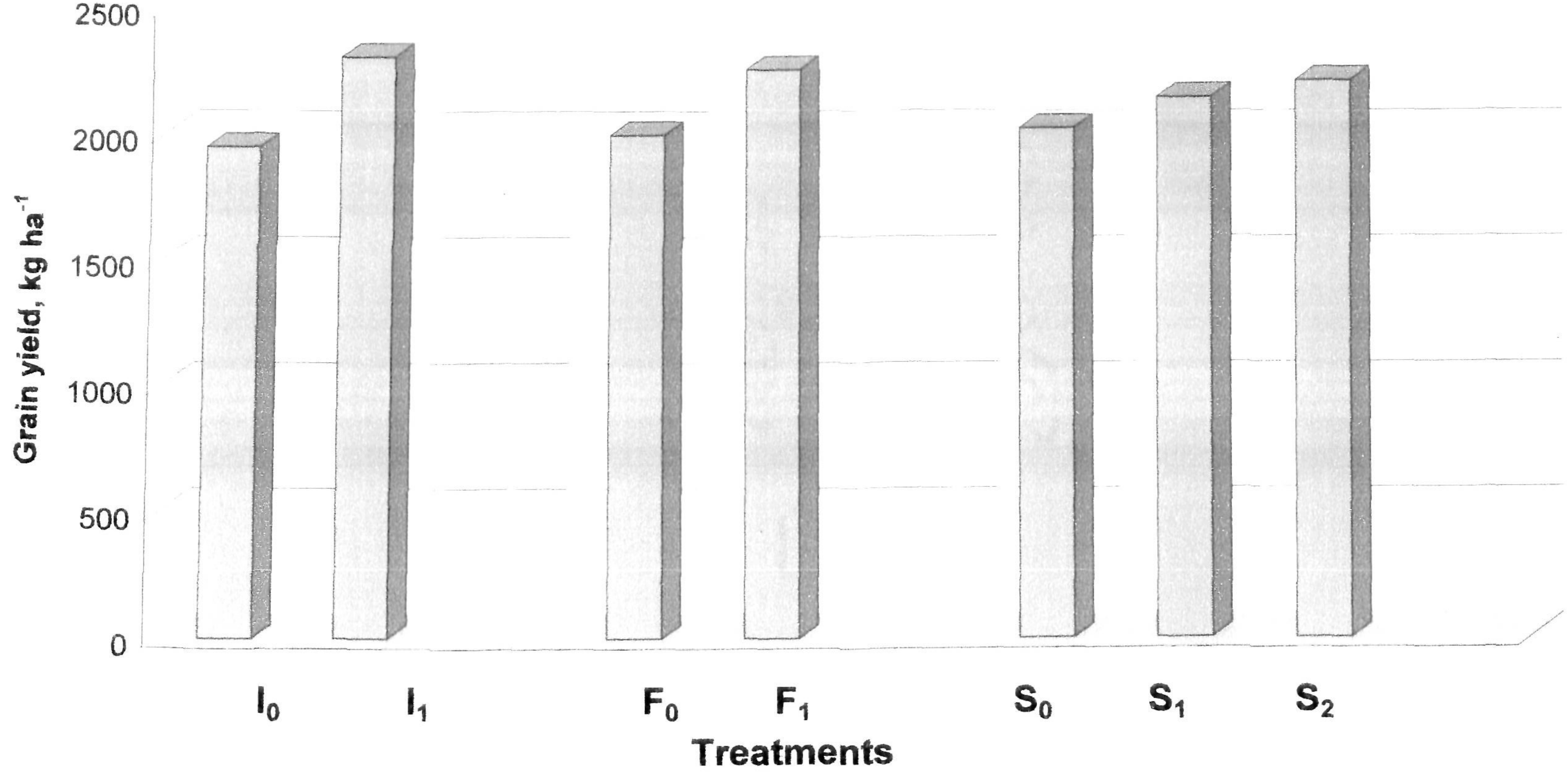

Fig. 4.5. **Grain yield as influenced by different levels of irrigation, FYM and sulphur**

4.2.3.1. Effect of irrigation

A perusal of data (Table 4.8) indicates that the grain yield of chickpea significantly influenced by different levels of irrigation. Irrigation schedule consisting irrigation applied at sowing and at flowering stage (I_1) showed its significant superiority over irrigation schedule having only one irrigation applied at sowing.

Table: 4.8. Grain yield (kg ha^{-1}) and straw yield (kg ha^{-1}) of chickpea as influenced by different levels of irrigation, FYM and sulphur treatments

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Irrigation (I)		
I_0- Pre-sowing irrigation	1950.92	2611.66
I_1- Pre-sowing irrigation + at flowering stage	2310.70	3228.04
S.Em. ±	58.18	54.08
C.D. (P= 0.05)	186.10	172.99
FYM (F)		
F_0- 0 tone FYM ha^{-1}	2001.96	2753.79
F_1- 10 tone FYM ha^{-1}	2259.66	3085.91
S.Em. ±	58.18	54.08
C.D. (P= 0.05)	186.10	172.99
C.V. %	13.38	9.07
Sulphur (S)		
S_0- 0 kg sulphur ha^{-1}	2026.48	2746.94
S_1-20 kg sulphur ha^{-1}	2151.30	2947.11
S_2-40 kg sulphur ha^{-1}	2214.65	3065.50
S.Em. ±	44.72	50.69
C.D. (P= 0.05)	130.52	147.95
C.V. %	8.39	6.94
Sig. Interaction	NS	NS

4.2.3.2. Effect of FYM

Application of FYM had also shown its significant effect on grain yield of chickpea. FYM application significantly increased the grain yield wherein F_1 gave significantly higher grain yield than F_0.

4.2.3.3. Effect of sulphur

The differences in grain yield of chickpea due to varying levels of sulphur were found significant. Though, S_1 and S_2 did not differ significantly from each other, they showed their superiority over S_0 with respect to grain yield. The magnitude of mean increase in grain yield with S_1 and S_2 was 6.16 and 9.29 per cent over S_0.

4.2.3.4. Interaction effects

None of the interactions was found to be significant with respect to grain yield.

4.2.4. Straw yield (kg ha^{-1})

The mean data in respect of straw yield as influenced by different levels of irrigation, FYM and sulphur treatment are presented in Table 4.8 and graphically depicted in Fig. 4.6.

4.2.4.1 Effect of Irrigation

A close examination of data (Table 4.8) indicates that different levels of irrigation manifest significant increase in straw yield. Irrigation treatment I_1 (pre-sowing + flowing stage) produced significantly the higher straw yield (3228.04 kg ha^{-1}) as compared to I_0 treatment (only pre-sowing irrigation).

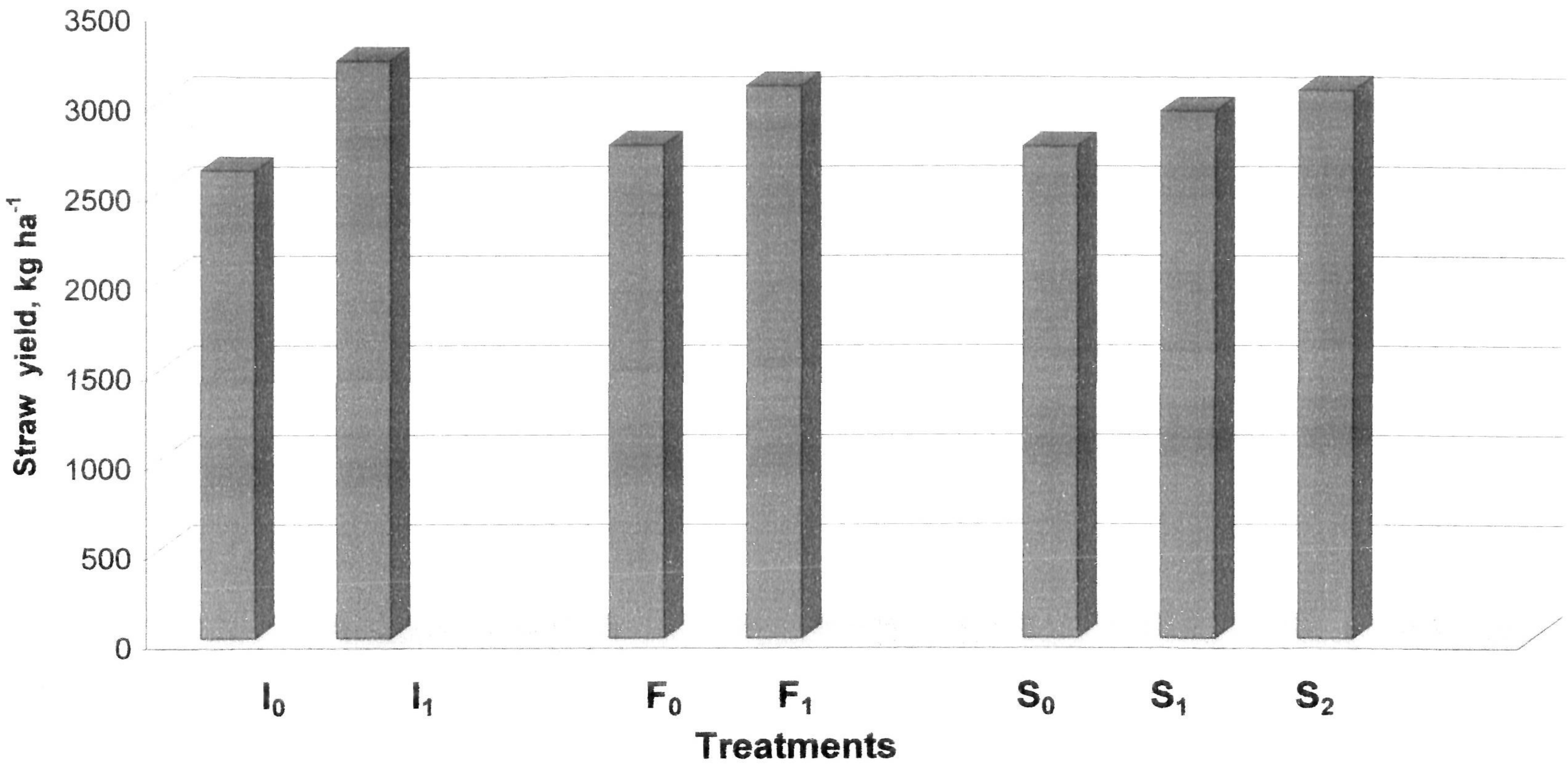

Fig. 4.6. **Straw yield as influenced by different levels of irrigation, FYM and sulphur**

4.2.4.2 Effect of FYM

Data furnished in Table 4.8 indicated that the two levels of FYM differed significantly between themselves in respect to straw yield. Application of FYM @ 10 t ha^{-1} (F_1) produced significantly the higher straw yield (3085.91 kg ha^{-1}) than no application of FYM (2753.79 kg ha^{-1}).

4.2.4.3 Effect of sulphur

Statistical analysis of data (Table 4.8) revealed that sulphur application (S_1 and S_2) significantly increased straw yield of chickpea over no application (S_0). The treatment S_1 and S_2 being at par produced significantly more straw yield than S_0. The highest straw yield of 3065.50 and 2947.11 was recorded under S_2 and S_1 respectively while, lowest of 2746.94 kg ha^{-1} registered under S_0.

4.2.4.4 Interaction effects

The effect of all possible interactions of various treatments were non significant.

4.2.5 Test weight (g)

Data on test weight as influenced by different levels of irrigation, FYM and sulphur treatments are presented in Table 4.9.

4.2.5.1 Effect of irrigation

A perusal of data given in Table 4.9 indicates that 1000 seeds weight was significantly influenced by irrigation treatments. Application of irrigation applied at sowing and at flowering stage (I_1) produces significantly the highest test weight (139.61) than irrigation applied at sowing only (I_0)

Table: 4.9. Test weight (g) and harvest index (%) as influenced by different levels of irrigation, FYM and sulphur treatments

Treatment	Test weight (1000 seeds) (g)	Harvest index (%)
Irrigation (I)		
I_0- Pre-sowing irrigation	132.22	42.57
I_1- Pre-sowing irrigation + at flowering stage	139.61	41.32
S.Em. ±	2.20	0.42
C.D. (P= 0.05)	7.05	NS
FYM (F)		
F_0- 0 tone FYM ha^{-1}	136.67	41.82
F_1- 10 tone FYM ha^{-1}	135.16	42.07
S.Em. ±	2.20	0.42
C.D. (P= 0.05)	NS	NS
C.V. %	7.94	4.96
Sulphur (S)		
S_0- 0 kg sulphur ha^{-1}	131.67	42.27
S_1-20 kg sulphur ha^{-1}	136.79	41.91
S_2-40 kg sulphur ha^{-1}	139.29	41.65
S.Em. ±	2.07	0.32
C.D. (P= 0.05)	6.04	NS
C.V. %	6.09	3.03
Sig. Interaction	NS	NS

4.2.5.2 Effect of FYM

Data furnished in Table 4.9 revealed that apparently, the test weight was found to be higher under F_1 (10 tonnes ha^{-1}) than F_0 (no FYM), but the effects of FYM on test weight was non significant.

4.2.5.3 Effect of sulphur

It is apparent from the data presented in Table 4.9 that the test weight was affected significantly due to sulphur levels. Although linear increase in test weight was noticed with the increasing levels of sulphur. The difference between S_1 and S_2 was not significant. The lowest sulphur level (S_0) recorded significantly the lowest value of test weight.

4.2.5.4 Interaction effects

The interaction among the levels of irrigation, FYM and sulphur did not induce significant variation in the test weight.

4.2.6 Harvest index (%)

Data on harvest index as influenced by varying levels of irrigation, FYM and sulphur treatments are presented in Table 4.9.

4.2.6.1 Effect of irrigation, FYM and sulphur treatments

A perusal of data given in Table 4.9 revealed that different levels of irrigation, FYM and sulphur treatments failed to show significant influence on the harvest index (%).

4.2.6.2 Interaction effects

The interaction effect was also absent.

4.3 QUALITY CHARACTERS

4.3.1 Nitrogen content in seed (%)

The data pertaining to nitrogen content of chickpea grain as influenced by different levels of irrigation, FYM and sulphur treatments are presented in Table 4.10.

4.3.1.1 Effect of Irrigation

It is obvious from the data (Table 4.10) that the difference in nitrogen content of grain was found significant due to irrigation schedule. Irrigation at pre-sowing + flowering stage (I_1) showed its superiority over I_0 (only pre-sowing irrigation) with respect to the nitrogen content of grain. The data on nitrogen content in grain were 3.17 and 2.81 percent with I_1 and I_0, respectively.

4.3.1.2 Effect of FYM

It was observed that the N-content in grain was significantly influenced due to FYM treatments. Treatment F_1 (10 t FYM ha^{-1}) recorded significantly the highest N-content (3.03 %) as compare to treatment of F_0 (2.95 %).

4.3.1.3 Effect of sulphur

It is apparent from the data (Table 4.10) that all the three levels of sulphur differed significantly from each other with respect to nitrogen content in grain and the response was linear. Significantly the highest nitrogen content was recorded with the highest level of sulphur and the lowest one with lowest level of sulphur.

4.3.1.4 Interaction effects

Analysis of data indicates that interaction effect was found to be non-significant with respect to nitrogen content of chickpea grain.

Table: 4.10. Nitrogen content, protein content and sulphur content in grain (%) as influenced by different levels of irrigation, FYM and sulphur treatments

Treatment	Nitrogen content (%) in grain	Protein content (%) in grain	Sulphur content (%) in grain
Irrigation (I)			
I_0- Pre-sowing irrigation	2.81	17.56	0.25
I_1- Pre-sowing irrigation + at flowering stage	3.17	19.82	0.26
S.Em. ±	0.02	0.13	0.003
C.D. (P= 0.05)	0.07	0.43	0.01
FYM (F)			
F_0- 0 tone FYM ha^{-1}	2.95	18.43	0.25
F_1- 10 tone FYM ha^{-1}	3.03	18.95	0.26
S.Em. ±	0.02	0.13	0.004
C.D. (P= 0.05)	0.07	0.43	NS
C.V. %	3.54	3.54	5.97
Sulphur (S)			
S_0- 0 kg sulphur ha^{-1}	2.65	16.58	0.21
S_1-20 kg sulphur ha^{-1}	3.11	19.41	0.26
S_2-40 kg sulphur ha^{-1}	3.21	20.07	0.30
S.Em. ±	0.02	0.12	0.003
C.D. (P= 0.05)	0.06	0.36	0.01
C.V. %	2.60	2.61	6.26
Sig. Interaction	NS	NS	NS

4.3.2 Protein content (%)

Mean value of protein content of chickpea grain as influenced by different level of irrigation, FYM and sulphur treatments are presented in Table 4.10.

4.3.2.1 Effect of irrigation

The data presented in Table 4.10 reveal that protein content of chickpea grain was significantly influenced due to levels of irrigation. Treatment I_1 (pre sowing irrigation+ at flowering stage) significantly enhanced the protein content in grain than I_0 (only pre sowing irrigation).

4.3.2.1 Effect of FYM

Analysis of data on protein content in grain influenced significantly due to FYM application. Treatment F_1 (10 t FYM ha^{-1}) was significantly better than F_0 (no FYM) in increasing the protein content in grain of chickpea.

4.3.2.3 Effect of sulphur

Significant response was observed on protein content in grain due to sulphur levels. It was further observed that there was a linear response and the protein content was increased significantly with each successive increase in the levels of applied sulphur.

4.3.2.4 Interaction effects

Result indicated that none of the interactions was found significant with respect to protein content in seed.

4.3.3 Sulphur content (%)

The data pertaining to sulphur content in chickpea grain as influenced by different levels of irrigation, FYM and sulphur treatments are presented in Table 4.10.

4.3.3.1 Effect of irrigation

The results presented in Table 4.10 revealed that irrigation schedule had significant influence on sulphur content in chickpea grain. Between two levels of irrigation, I_1 level of irrigation recorded significantly higher sulphur content in grain than I_0.

4.3.3.2 Effect of FYM

Analysis of data on sulphur content in grain showed that FYM application did not manifest its significant effect on sulphur content in grain of chickpea.

4.3.3.3 Effect of sulphur

Statistical analysis of data (Table 4.10) showed that application of sulphur significantly increased the sulphur content in grain. It was further noticed that the sulphur content in grain was increased significantly with each successive increase in the level of applied sulphur. The lowest sulphur content was recorded in absence of applied sulphur.

4.3.3.4 Interaction effects

All the interactions with respect to sulphur content in grain of chickpea were absent.

4.4 POST HARVEST SOIL NUTRIENT STATUS

4.4.1 Available Nitrogen (kg ha^{-1})

Data on post harvest available soil nitrogen status as influenced by different levels of irrigation, FYM and sulphur treatments are presented in Table 4.11.

4.4.1.1 Effect of Irrigation

Irrigation schedule did not show any significant variation in nitrogen status of soil after harvest of crop.

4.4.1.2 Effect of FYM

The differences in post harvest available nitrogen status in soil due to application of FYM were found significant. Application of FYM @ 10 tonnes ha^{-1} recorded significantly higher available nitrogen in soil than no application of FYM.

4.4.1.3 Effect of sulphur

The results revealed that the available nitrogen in the soil after harvest of the crop remained unchanged due to the application of sulphur.

4.4.1.4 Interaction effect

The interactions with respect to available N status of soil after harvesting of chickpea were absent.

4.4.2 Available phosphorus (kg ha^{-1})

Data on post harvest available soil phosphorus as influenced due to varying levels of irrigation, FYM and sulphur treatments are presented in Table 4.11.

Table: 4.11. Influence of irrigation, FYM and sulphur on nitrogen and phosphorus content in soil (kg ha^{-1}) after harvesting of chickpea

Treatment	Nitrogen content in soil after harvest (kg ha^{-1})	Phosphorus content in soil after harvest (kg ha^{-1})
Irrigation (I)		
I_0- Pre-sowing irrigation	218.72	28.63
I_1- Pre-sowing irrigation + at flowering stage	217.75	36.38
S.Em. ±	8.73	0.50
C.D. (P= 0.05)	NS	1.61
FYM (F)		
F_0- 0 tone FYM ha^{-1}	203.13	30.42
F_1- 10 tone FYM ha^{-1}	233.33	34.58
S.Em. ±	8.73	0.50
C.D. (P= 0.05)	27.92	1.61
C.V. %	19.60	7.58
Sulphur (S)		
S_0- 0 kg sulphur ha^{-1}	223.88	32.69
S_1-20 kg sulphur ha^{-1}	212.44	32.88
S_2-40 kg sulphur ha^{-1}	218.38	31.94
S.Em. ±	12.07	0.60
C.D. (P= 0.05)	NS	NS
C.V. %	22.13	7.39
Sig. Interaction	NS	NS

4.4.2.1 Effect of irrigation

The difference in post harvest available soil phosphorus status due to varying irrigation levels was found significant. Significantly the higher available phosphorus status was recorded under I_1 (36.38) than I_0 irrigation level (28.63).

4.4.2.2 Effect of FYM

FYM application had significantly influenced on post harvest available phosphorus content in soil. Significantly the highest available P_20_5 status was recorded under F_1 (34.58) rate as compare to F_0 (30.42).

4.4.2.3 Effect of sulphur

The difference in post harvest phosphorus status due to varying level of sulphur was found to be non-significant.

4.4.2.4 Interaction effects

The interactions with respect to available P_2O_5 status of soil after harvesting of chickpea were absent.

4.4.3 Available potash (kg ha^{-1})

Data on post harvest available potash as influenced by various treatments of irrigation, FYM and sulphur are presented in Table 4.12.

4.4.3.1 Effect of irrigation, FYM and sulphur

The results presented in Table 4.12 reveal that the irrigation, FYM and sulphur treatments did not alter a significant influence on available K_20 of the soil after harvest of crop.

4.4.3.2 Interaction effects

None of the interaction was also found to be significant with respect to post harvest available potash content in soil.

Table: 4.12. Influence of irrigation, FYM and sulphur on potash and sulphur content in soil (kg ha^{-1}) after harvesting of chickpea

Treatment	Potash content in soil after harvest (kg ha^{-1})	Sulphur content in soil after harvest (kg ha^{-1})
Irrigation (I)		
I_0- Pre-sowing irrigation	277.79	23.17
I_1- Pre-sowing irrigation + at flowering stage	269.25	22.91
S.Em. ±	14.18	0.47
C.D. (P= 0.05)	NS	NS
FYM (F)		
F_0- 0 tone FYM ha^{-1}	274.25	22.93
F_1- 10 tone FYM ha^{-1}	272.79	23.15
S.Em. ±	14.18	0.47
C.D. (P= 0.05)	NS	NS
C.V. %	25.40	9.93
Sulphur (S)		
S_0- 0 kg sulphur ha^{-1}	266.31	18.29
S_1-20 kg sulphur ha^{-1}	273.13	24.33
S_2-40 kg sulphur ha^{-1}	281.13	26.50
S.Em. ±	10.32	1.63
C.D. (P= 0.05)	NS	4.75
C.V. %	15.09	28.24
Sig. Interaction	NS	NS

4.4.4 Available sulphur (kg ha^{-1})

Data on post harvest available sulphur in the soil as influenced due to varying levels of irrigation, FYM and sulphur treatments are presented in Table 4.12.

4.4.4.1 Effect of irrigation and FYM

The data present in Table 4.12 reveal that the irrigation and FYM treatments did not show any significant influence on available potash of the soil after harvesting of chickpea.

4.4.4.2 Effect of sulphur

The difference in post harvest sulphur status of soil due to varying levels of sulphur treatments was found to be significant. Treatment S_2 recorded highest available sulphur content in the soil, which being at par with S_1 varied significantly with S_0. The lowest post harvest available sulphur status of soil was observed under S_0.

4.4.4.3 Interaction effects

The interactions effect was absent.

4.4.5 Moisture content (%) at flowering stage (50 DAS)

Data on moisture content at flowering stage (50 DAS) as influenced by different level of irrigation, FYM and sulphur treatments are presented in Table 4.13.

4.4.5.1 Effect of irrigation

Data presented in Table 4.13 indicated that different levels of irrigation significantly affected the moisture content in the soil. Significantly the highest moisture content was observed in I_1 (17.22 %) treatment as compare to I_0 (15.89 %) treatment.

Table: 4.13. Moisture content in soil at flowering (50 DAS) and at pod development stage (90 DAS) as influenced by different levels of irrigation, FYM and sulphur treatments

Treatment	Moisture content in soil at flowering stage (50 DAS) (%)	Moisture content in soil at pod development stage (90 DAS) (%)
Irrigation (I)		
I_0- Pre-sowing irrigation	15.89	9.06
I_1- Pre-sowing irrigation + at flowering stage	17.22	12.40
S.Em. ±	0.09	0.06
C.D. (P= 0.05)	0.29	0.20
FYM (F)		
F_0- 0 tone FYM ha^{-1}	15.46	10.19
F_1- 10 tone FYM ha^{-1}	17.65	11.27
S.Em. ±	0.09	0.06
C.D. (P= 0.05)	0.29	0.20
C.V. %	2.55	2.83
Sulphur (S)		
S_0- 0 kg sulphur ha^{-1}	16.99	10.69
S_1-20 kg sulphur ha^{-1}	17.00	10.69
S_2-40 kg sulphur ha^{-1}	17.41	10.82
S.Em. ±	0.10	0.07
C.D. (P= 0.05)	0.29	NS
C.V. %	2.32	2.55
Sig. Interaction	I × F	I × F F × S

4.4.5.2 Effect of FYM

The results presented in Table 4.13 reveal that the FYM treatments exert significant influence on moisture content in soil at flowering stage. The FYM (F_1) application helped in retaining significantly more moisture in soil at flowering stage over no application of FYM (F_0).

4.4.5.3 Effect of sulphur

A close examination of data (Table 4.13) indicates that the moisture content in soil at flowering stage (50 DAS) significantly influenced due to varying levels of sulphur. It was further observed that sulphur at S_2 rate recorded highest moisture content at flowering stage (50 DAS), which was significantly superior over S_1 and S_0. Significantly the lowest value of moisture content was observed under S_0.

4.4.5.4 Interaction effects

Interaction, irrigation × FYM was found significant in respect of moisture content in soil at flowering stage (50 DAS) (Table 4.14). Treatment combination I_1F_1 (18.01 %) recorded significantly the highest moisture content in soil at flowering stage, which remained at par with I_0F_1 (17.29 %). The lowest moisture content in soil at flowering stage was found under I_0F_0 (14.49 %) treatment combination.

Table: 4.14. Moisture content in soil at flowering stage as influenced by I × F interaction

Treatment	FYM (F)	
Irrigation (I)	F_0	F_1
I_0	14.49	17.29
I_1	16.43	18.01
S.Em. ±	0.24	
C.D. (P= 0.05)	0.75	
C.V. %	2.55	

4.4.6 Moisture content (%) in soil at pod development stage (90 DAS)

Data on moisture content in soil at pod development stage (90 DAS) as influenced due to varying levels of irrigation, FYM and sulphur treatments are presented in Table 4.13.

4.4.6.1 Effect of irrigation

Data furnished in Table 4.13 indicated that different levels of irrigation significantly affected the moisture content in soil at pod development stage (90 DAS). Significantly the highest moisture content at pod development stage (90 DAS) was observed in I_1 (12.40 %) level of irrigation, while the lowest was under I_0 (9.06 %).

4.4.6.2 Effect of FYM

Results furnished in Table 4.13 reveal that FYM application significantly enhanced the moisture content in soil at pod development stage (90 DAS). It was observed higher in F_1 treatment (11.27 %) as compare to F_0 treatment (10.19 %).

4.4.6.3 Effect of sulphur

From the data (Table 4.13) it was observed that the differences in moisture content in soil at pod development stage (90 DAS) due to sulphur levels were found non significant.

4.4.6.4 Interaction effects

4.4.6.4.1 I×F interaction

Interaction, irrigation× FYM (Table 4.15) was found significant in respect of moisture content in soil at pod development (90 DAS). Treatment combination I_1F_1 (12.77 %) recorded significantly the highest moisture content at pod development stage (90 DAS) as compared to the rest of the treatment combinations. The lowest moisture content at pod development stage (90 DAS) was observed under I_0F_0 (8.34 %) treatment combination. It is interesting to note that in the presence or absence of irrigation at flowering stage (I_0 and I_1) application of FYM (F_1) recorded significantly higher moisture than F_0. Similarly, in presence or absence of FYM, irrigation I_1 level recorded significantly higher moisture than I_0.

Table: 4.15. Moisture content in soil at pod development stage (90 DAS) as influenced by I × F Interaction

Treatment	FYM (F)	
Irrigation (I)	F_0	F_1
I_0	8.34	9.78
I_1	12.03	12.77
S.Em. ±	0.09	
C.D. (P= 0.05)	0.28	
C.V. %	2.83	

4.4.6.4.2 F×S interaction

The statistical analysis of F × S interaction (Table 4.16) revealed that significantly the highest moisture content at pod development stage (90 DAS) (11.37 %) was recorded under F_1S_1 and F_1S_0 (11.32 %) combinations. The F_0S_0 and F_0S_1 recorded the lowest moisture content.

Table: 4.16. Moisture content in soil at pod development stage (90 DAS) as influenced by F × S Interaction

Treatment FYM (F)	Sulphur (S) S_0	S_1	S_2
F_0	10.05	10.00	10.50
F_1	11.32	11.37	11.13
S.Em. ±		0.10	
C.D. (P= 0.05)		0.28	
C.V. %		2.55	

4.5 ECONOMICAL EVALUATION

The details of income, total expenses and CBR for individual treatment and their combinations are worked out and presented in Table 4.17 and Table 4.18. The cost of cultivation of chickpea and other details of cost incurred in treatments application are furnished in Appendices- II.

Table: 4.17. Gross, net realization and cost benefit ratio (CBR) for different treatments of irrigation, FYM and sulphur treatments

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Gross realization (Rs ha^{-1})	Total cost of cultivation (Rs ha^{-1})	Net realization (Rs ha^{-1})	C.B.R.
Irrigation schedule (I)						
I_0	1951	2612	31869	8367	23502	1: 3.81
I_1	2311	3228	37783	8709	29094	1: 4.34
FYM (F)						
F_0	2002	2754	32721	7802	24919	1: 4.19
F_1	2260	3086	36932	9279	27653	1: 3.98
Sulphur (S)						
S_0	2026	2747	33103	8443	24660	1: 3.92
S_1	2151	2947	35153	8557	26596	1: 4.11
S_2	2215	3066	36207	8614	27593	1: 4.20

Note : Selling price of produce, Grain Rs. 16 kg^{-1}, Straw Rs. 0.25 kg^{-1}

Table: 4.18. Economics of different treatment combinations

Treatment combi-nations	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Gross realization		Total realization (Rs ha^{-1})	Total cost of cultivation (Rs ha^{-1})	Net Realiza-tion (Rs ha^{-1})
			Grain (Rs ha^{-1})	Straw (Rs ha^{-1})			
$I_0F_0S_0$	1714	2258	27424	565	27989	7531	20458
$I_0F_0S_1$	1898	2518	30368	630	30998	7645	23353
$I_0F_0S_2$	1912	2633	30592	658	31250	7702	23548
$I_0F_1S_0$	1992	2635	31872	659	32531	9013	23518
$I_0F_1S_1$	2072	2782	33152	696	33848	9127	24721
$I_0F_1S_2$	2116	2843	33856	711	34567	9184	25383
$I_1F_0S_0$	2052	2848	32832	712	33544	7873	25671
$I_1F_0S_1$	2172	3058	34752	765	35517	7987	27530
$I_1F_0S_2$	2263	3207	36208	802	37010	8044	28966
$I_1F_1S_0$	2347	3246	37552	812	38364	9355	29009
$I_1F_1S_1$	2463	3430	39408	856	40266	9469	30797
$I_1F_1S_2$	2567	3579	41072	895	41967	9526	32441

4.5.1 Effect of irrigation

It is apparent from Table 4.17 that when chickpea crop was irrigated at pre-sowing+ flowering stage (I_1), it realized maximum net return of Rs 29094 ha^{-1} as compared to only pre-sowing (I_0) given to chickpea crop which gave Rs 23502 ha^{-1}. In case of cost benefit ratio (CBR), treatment I_1 ranked first recorded CBR of 1: 4.34 followed by treatment I_0 (1:3.81 CBR).

4.5.2 Effect of FYM

The maximum net return of Rs 27653 and the net CBR of 1: 3.98 were obtained under the application of FYM (@ 10 tonnes ha^{-1}). The net return was obtained higher by Rs 2734 over no application of FYM (F_0).

4.5.3 Effect of sulphur

There was an appreciable increase in net realization due to sulphur application as shown in Table 4.17. Increasing trend in net return was observed with each successive increase in sulphur level. The highest net return of Rs 27593 was secured with 40 kg S ha^{-1} (S_2), followed by Rs 26596 with 20 kg S ha^{-1} (S_1). The lowest value of Rs 24660 was recorded with no application of sulphur (S_0). An application of 40 kg sulphur per hectare secured 3.75 and 11.89 percent more net realization over 20 and 0 kg S ha^{-1}, respectively. It was also apparent from the data in case of sulphur that the treatment S_2 (40 kg S ha^{-1}) gave the highest CBR of 1: 4.20 followed by S_1 (20 kg S ha^{-1}) treatment (1: 4.11) and S_0 (1: 3.92).

It was evident from the data presented from Table 4.18 the highest net returns worth Rs 32441 ha^{-1} were secured under treatment combination $I_1F_1S_2$ (pre-sowing irrigation + at flowering stage, 10 t FYM ha^{-1} and 40 kg S ha^{-1}) followed by $I_1F_1S_1$ with Rs 30797 ha^{-1} (pre-sowing irrigation + at flowering stage, 10 t FYM ha^{-1} and 20 kg S ha^{-1}) and $I_1F_1S_0$ with Rs 29009 ha^{-1} (pre-sowing irrigation + at flowering stage, 10 t FYM ha^{-1}). The lowest profit of Rs 20458 ha^{-1} was noted with $I_0F_0S_0$ (without post sowing irrigation, FYM and sulphur).

DISCUSSION

V. DISCUSSION

A brief discussion on results obtained from the present investigation entitled "Influence of irrigation, FYM and sulphur on growth, yield and quality of chickpea (*Cicer arientinum* L.) under middle Gujarat conditions" has been presented in this chapter. It has been attempted to establish effect and cause relationship in light of variable evidences and literature. The results of this investigation showed that growth characters, yield attributes and quality parameters and yield depend on water regime, organic manure and sulphur application. The factors, which affect the growth and development, yield and quality of the crop, are discussed in this chapter.

5.1 EFFECT OF CLIMATE

The climate needed for the normal healthy growth and development of the chickpea crop prevailed during the study as evident from the data recorded at the Meteorological Observatory (Table 3.1) and from the observation recorded on growth and development of the crop. The total rainfall recorded during 2002-03 was 788.00 mm, received in 26 rainy days and was less than average rainfall of 825.0 mm of this area. The adversities of climate like occurrence of frost or unseasonal rains did not occur during crop growth period.

5.2 Plant population

To obtain maximum possible yield, it is essential for the crop to utilized equitably and efficiently all available factors viz., water, nutrient, light and CO_2. This could be achieved by uniform plant population. Plant stand during initial stage was maintained uniformly by thinning and gap filling. Consequently, the plant population in all the experimental plots at the time of harvest was uniform (Table 4.1). None of the treatments significantly influenced the plant stand. This indicates that whatever differences were observed in growth and yield attributes were mainly due to treatment effect.

5.3 EFFECT OF IRRIGATION

Chickpea in India is usually grown on well-conserved soil moisture. Though, generally soil moisture is depleted much after the harvest of preceding crop, which necessiates the pre-sowing irrigation. Many research workers have also observed that the flowering stage in chickpea is most sensitive stage to water stress as far as quantity and quality of harvest are concerned. To evaluate the proper irrigation schedule for above situation, this investigation was undertaken.

5.3.1 Growth attributes

The results in respect of plant height measured at 30 and 60 DAS and at harvest (Table 4.2) indicated that irrigation schedule did not influence the plant height at 30 DAS. This could be due to initially adequate moisture content in soil under both the irrigation treatment, which had equally influenced the initial growth as evident from the data on plant height. However, irrigation levels increased plant height at 60

DAS and at harvest. The higher plant height under I_1 treatment at both stages was mainly because of one supplemental irrigation received in this treatment during flowering stage (active growth stage) might have provided congenial condition for favourable growth in terms of cell division and expansion and thereby stem elongation that virtually increased plant height. Similar effect of irrigation on plant height was observed by Mandal *et al.* (1979).

In dicot plants, number of branches is one of the basic yield components. The results presented in Table 4.4 indicate that crop receiving pre-sowing irrigation in addition to irrigation at flowering stage (I_1) exerted notable impact in improvement of number of branches per plant. Pre-sowing irrigation plus irrigation at flowering stage (I_1) produced significantly higher number of branches per plant than only pre-sowing irrigation (I_0). The growth of branches depends on progressive initiation of tissue and expansion of cell under this treatment due to adequate water supply which might have helped in nutrient mobilization and thereby making the plant physiologically more active. On the contrary, moisture stress conditions might have inactivated the aerial buds resulting in poor branching. The results are in agreement with the finding of Mandal *et al.* (1979) and Sharma (1994).

Number of nodules and dry weight of nodules per plant (Table 4.5) differed significantly due to irrigation treatments and these were recorded significantly higher under I_1 treatment than I_0. The improvement in root nodulation by maintaining the moisture with supply of pre and post sowing irrigation at flowering stage may be ascribed to improved physiological functions and production of adequate photosynthates for the use of *Rhizobia* in the process of root nodule formation.

5.3.2 Effect on yield and yield attributes

The yield attributes viz., number of pods per plant as well as grain yield per plant (Table 4.7) and test weight (Table 4.9) were significantly influenced by irrigation treatments. Number of pods per plant (Table 4.7) was significantly increased by increase in water supply. Treatment I_1 recorded significantly higher number of pods per plant (85.74) than I_0. The reduction in number of pods per plant in treatment receiving only pre-sowing irrigation could be due to increased moisture stress in plant which might have affected flowering proliferation and ultimately produced small and less number of pods, resulting in lower yield as evident from the data on grain yield per plant (Table 4.7) under I_0 as compare to I_1 treatment. Moreover, irrigation encouraged the vegetative growth and produced more branches, which provided loci for pod development and might have increased the photosynthetic capacity of the plant to create source for pod filling. Similar positive response of irrigation on number of pods per plant has been reported by Mandal *et al.* (1979) and Sharma (1994) and grain yield per plant by Grewal *et al.* (1984) and Sharma (1994).

The 1000 seeds weight at harvest (Table 4.9) was significantly influenced due to application of irrigation. Two irrigations one at pre-sowing and second at flowering stage (I_1) exhibited significant superiority with respect to 1000 seeds weight (139.69) as compare to only pre-sowing irrigation (I_0). The above findings are akin to those reported by Mandal *et al.* (1979) and Pawar *et al.* (1992).

A reference to the results with respect to grain yield (Table 4.8) indicated that irrigation levels had appreciably influenced the grain yield. Pre-sowing irrigation along with one supplemental irrigation at flowering stage (I_1) resulted into significantly higher grain yield as compare to only pre-sowing irrigation (I_0). The per cent increase in grain yield under I_1 over I_0 was 18.44. This was evidently due to the cumulative effect of improvement in growth and yield attributes such as plant height (Table 4.2), number of branches (Table 4.4), number of pods per plant, grain yield per plant (Table 4.7) and test weight (Table 4.9). These results are also in consonance with those reported by Grewal *et al.* (1984); Sharma (1994) and Maliwal *et al.* (1999).

Lower grain yield was registered under application of pre-sowing irrigation only. The marked reduction in grain yield may be due to water stress condition particularly during the reproductive stage, which might have affected the accumulation and translocation of photosynthates to the reproductive organs eventually affecting the yield. Karmar (1969) reported that closer of stomata tends to raise plant body temperature and increase the respiration; the process that leads to breakdown of assimilates. Hughes and Keatinge (1983) and Muchow (1969) observed the adverse effect to water stress on yield of grain legumes through cumulative effect of light interception (through effect of leaf area) and efficiency of conversion of dry matter to grain yield. Hence, moisture stress at flowering stage caused progressively adverse effect on growth and yield attributes, which have reflected on grain yield. Reduction in yields under one irrigation than two irrigations was also observed by Sharma (1994).

Like other attributes straw yield was also significantly influenced due to the irrigation treatments (Table 4.8). Treatment I_1 produced significantly the highest straw yield. The increase in straw yield was 23.60 per cent over I_0. Profound increase of growth attributes such as plant height and number of branches might be responsible for higher straw yield. Higher straw yield with post-sowing irrigation in chickpea was also reported by Singh *et al.* (1980), Grewal *et al.* (1984), Sharma (1994) and Maliwal *et al.* (1998).

Harvest index (Table 4.9) of chickpea remain unchanged due to irrigation schedule. This was probably due to corresponding increase in both grain and straw yields.

5.3.3 Effect on quality characters

It is an established fact that application of irrigation water increase solubility and degree of ionization of nutrients in soil and hence the availability of nutrients increases. Secondly, the mobility of nutrients with increase in moisture content of soil and *vice versa* (Tisdale and Nelson, 1985).

The results in respect to nitrogen content in grains showed significant variation due to irrigation treatments (Table 4.10). Pre-sowing irrigation plus irrigation at flowering stage (I_1) resulted into significantly higher nitrogen content than only pre-sowing irrigation (I_0).

Similar trend was also noted for protein content in grain of chickpea (Table 4.10). Treatment I_1 (pre-sowing irrigation + irrigation at flowering stage) recorded significantly higher protein content (19.82%) than I_0 (only pre-sowing irrigation). Application of irrigation at pre-sowing plus at flowering stage (I_1) may sustained better moisture condition in soil as evident from the data on soil moisture content at flowering (50 DAS) and at pod development stage (90 DAS) (Table 4.13). This may increase the availability of nitrogen and finally the nitrogen content in grain, resulting into higher protein content in grain.

Like-wise other quality parameters such as sulphur content in grain (Table 4.10) differed significantly due to irrigation level. The highest sulphur content in grain was observed in I_1 (pre-sowing irrigation + at flowering stage) than I_0 level. The increase in sulphur content under irrigation may be due to more availability of sulphur, which might have resulted in higher sulphur content in seed (Table 4.10).

5.3.4 Effect on post-harvest soil nutrient and soil moisture status

The data cited in the Table 4.11 and 4.12 indicated that application of irrigation did not show significant difference for post-harvest soil available N, K_2O and S. Whereas the post-harvest soil available P_2O_5 was significantly differed due to irrigation treatment. The highest post-harvest soil available P_2O_5 was observed under I_1 (pre-sowing irrigation + at flowering stage) as compare I_0 (only pre-sowing irrigation). This might be due to more phosphorus dissolution and less fixation in soil at higher moisture level resulting in higher post-harvest soil available P_2O_5.

Moisture content in soil at flowering stage (50 DAS) and at pod development stage (90 DAS) differed significantly due to irrigation treatments and these were recorded significantly higher under I_1 treatment than I_0 (Table 4.13). This might be due to supplemental irrigation applied at flowering stage in I_1 treatment store enough moisture in the soil and considerably sustain up to harvest.

5.4 EFFECT OF FYM

Besides nutritional effects, application of farmyard manure helps in improvement of soil physical environment which stimulate the root growth and increase the capacity of plant for efficient utilization of nutrients and soil moisture, resulting better growth of crop. Keeping this in view, effects of FYM were studied on different growth and yield attributes, yield and quality of chickpea as well as soil moisture condition at later growth stage of crop under limited water supply to crop.

5.4.1 Effect on growth attributes

The results in respect of plant height measured at 30 and 60 DAS and at harvest (Table 4.2) indicate that plant height at 30 DAS and at harvest showed non-significant response to FYM application. Plant height recorded at 60 DAS increased significantly by application of FYM (10 t ha^{-1}) over no FYM (0 t ha^{-1}). These results are substantiated with Raju and Verma (1984) and Gangawar and Singh (1992).

The results pertaining to number of branches per plant showed significant response to FYM application. FYM upon decomposition increase the availability of essential nutrients to the plants also provide better atmosphere for root development resulted in more vegetative growth. The results are in conformity with those of Gangwar and Singh (1992).

While studying the effect of FYM application on nodulation, significant increase in nodulation due to FYM was observed (Table 4.5). Higher number of nodules with FYM may be stemmed from better root growth, which facilited more area for nodule formation. Micronutrients in FYM, especially 'B' and 'Co' and enzymes and co-enzymes of intricate biochemical composition might have also stimulated nodulation (Raju *et al.*, 1991 and Vadavia *et al.*, 1991).

Significant differences were also observed in nodule dry weight due to FYM application (Table 4.5). Similar observation was also made by Vadavia *et al.* (1991).

5.4.2 Effect on yield and yield attributes

Number of pods per plant (Table 4.7) was significantly enhanced with the application of FYM. This increase was to the tune of 18.00 per cent over no application. This might be due to the fact that FYM application increased availability of essential plant nutrients which enhanced root and shoot development and thereby growth. Thereafter, it might have influenced the reproductive phase and induced flowering, which resulted in increased number of pod and grain yield per plant. Such beneficial effect of FYM have been demonstrated by Vadavia *et al.* (1991) and Gangawar and Singh (1992).

The trend in results of grain yield per plant (Table 4.7) resembled with that of number of pods per plant (Table 4.6). Grain yield per plant showed significant increase with the application of FYM over no FYM application. This increase was 23.96 per cent higher than no application of FYM. These results are in close conformity with those of Shah (1995).

Crop yield is the complex function of physiological processes and biochemical activities, which modify plant anatomy and morphology of the growing plants. Judicious quantity of available nutrients is a basic requirement throughout the crop growth period for smooth running of all physiological processes. The results presented in Table 4.8 showed significant increase of total seed yield with FYM application. Between the two levels of FYM, F_1 recorded an increase of 257.70 kg seed yield ha^{-1} over F_0. The per cent increase in seed yield at F_1 over F_0 was 12.87. This was evidently due to the cumulative effect of improvement in growth and yield attributes such as number of branches (Table 4.4), number of pods (Table 4.7) and grain yield per plant (Table 4.7) as well as nitrogen content in seed and moisture retention in soil during the crop growth period. These findings are in accordance with those of Raju and Verma (1984), Patel and Patel (1991), Shivkumar *et al.* (2002) and Meena and Singh (2002).

Just like grain yield, 12.06 per cent straw yield was increased with FYM application over no application. This increase was attributed to the increased growth and yield attributing characters as described earlier in case of grain yield. This result is supported by Raju and Verma (1984).

The results with respect to test weight visualize that application of FYM did not exert significant influence on test weight (Table 4.9). Similar results were obtained by Raju and Verma (1984) and Patel and Patel (1991).

Similar to test weight, harvest index (Table 4.9) of chickpea was not significantly affected due to FYM application. This was because of corresponding increase in both grain and straw yields.

5.4.3 Effect on quality characters

The significant increase in nitrogen content to the tune of 2.71 per cent over F_0 was observed (Table 4.10). The increase in nitrogen content in grain might be due to more availability and uptake of nitrogen through FYM application.

Protein content in seed (Table 4.10) was also significantly increased with the application of FYM. Nitrogen being a constituent of various essential metabolites including protein and amino acids, the increase might be due to more availability and uptake of nitrogen through FYM application resulted in higher protein content. This was clearly evident from the results of present study on nitrogen content in grain.

The result with respect to sulphur content in grain visualize that application of FYM did not show significant influence on sulphur content (Table 4.10).

5.4.4 Effect on post-harvest soil nutrient and soil moisture status

The data presented in the Table 4.11 and 4.12 indicate that application of FYM did not exert significant difference for post-harvest soil available K_2O and S, whereas the available nitrogen was observed significantly higher under FYM application this might be due to decomposition of FYM resulting in higher post-harvest nitrogen in soil, while the available phosphorus was also observed significantly higher under F_1 (10 tonnes ha^{-1}) this may be due to decomposition of FYM, the organic acid formed which increased the available soil phosphorus by dissolving the acid soluble phosphorus resulting in higher post-harvest phosphorus status of soil. This result is corroborated with findings of Raju and Verma (1984).

Moisture content in soil at flowering (50 DAS) and at pod development stage (90 DAS) was differed significantly due to FYM application and this was recorded higher under F_1 treatment (10 tonnes ha^{-1}) than F_0 (Table 4.13). This might be due to FYM application, which increase water-holding capacity of soil as well as act as mulch, which resulted into higher moisture content in soil.

5.5 EFFECT OF SULPHUR

Sulphur is important for the synthesis of essential amino acids like methionine, cysteine and cystine which are important for protein synthesis thereby, affecting the growth and yield as well as quality of legume grains. It also promotes nodulation.

5.5.1 Effect on growth attributes

Sulphur (S_1 and S_2) had significantly increased the plant height of chickpea at 60 DAS. On the contrary, the height at initial stage (30 DAS) and at harvest remained unaltered by the sulphur application. These results are substantiated with Singh and Yadav (1997).

Sulphur application had significantly increased the number of branches per plant. Results for branches indicated 20 kg S ha^{-1} as an optimum level, there was not much gain in increasing the dose beyond 20 kg S ha^{-1}. The superiority of sulphur was established because it act as metabolites of growing plants which is directly related with cell division, enlargement, elongation and differentiation. Similar observation was also made by Singh and Yadav (1997) and Shivkumar *et al.* (2002).

The results pertaining to number of nodule per plant showed significant response to sulphur treatment (Table 4.5). The number of nodule per plant increases with increase in the graded dose of sulphur. This might be due to sulphur play a vital role in formation of ferredoxin-an iron containing plant protein that acts as an electron carrier in photosynthesis and involved in N fixation by nodule bacteria. These findings are in accordance with those reported by Shinde and Saraf (1992) and Joseph and Verma (1994).

While significant differences were also observed in nodule dry weight due to sulphur application and same trend observed as per number of nodule per plant (Table 4.5). Similar observations were also made by Sinde and Saraf (1992) and Singh and Yadav (1997).

5.5.2 Effect on yield and yield attributes

Sulphur besides improving vegetative growth, also activates certain proteolytic enzymes and it is also necessary for synthesis of certain vitamins and co-enzymes (Bixby and Beaton, 1970). Thus, these bio-activities of sulphur might have played important role in improving yield attributes like pods per plant and thereby grain yield per plant and also total grain yield in the present study (Table 4.8). The maximum grain yield was recorded under S_2 (40 kg S ha^{-1}) but it was at par with S_1 (20 kg S ha^{-1}). Therefore, the addition of sulphur at the rate of 20 kg ha^{-1} was optimum for improving the grain yield by 124.82 kg ha^{-1}. These finding confirm the earlier report of Joseph and Verma (1994), Saraf *et al.* (1997) and Ghosh and Sarkar (2000) who found 20 kg S ha^{-1} as an optimum level of sulphur for increasing the grain yield in chickpea.

Favourable effect of sulphur on test weight was also noted (Table 4.9). On an average, the increase in test weight at S_1 over S_0 was 5.12 gramme and S_2 over S_0 was 7.62 gramme, respectively. Though the difference between S_2 and S_1 was non-significant. The present findings are in close accordance with those reported by Saraf *et al.* (1997) and Tripathi *et al.* (1997).

On the contrary, sulphur effect was non-significant on harvest index. But it was significant for straw yield. The sulphur application at the rate of 20 kg ha^{-1} was found to be an optimum level as there was no significant difference between S_1 and S_2 levels. The present findings are in confirmation with those reported earlier by Joseph and Verma (1994), Ghosh and Sarkar (2000) and Singh *et al.* (2002).

5.5.3 Effect on quality characters

In present investigation, sulphur application significantly increased N-content of seed (Table 4.10). Such an increase of N-content in seed might be due to synergistic effects of both N and S, which were supplied to the crop. (Aulakh and Pasricha, 1983).

Almost similar trend was noticed in S-content in the seed. It was enhanced significantly with each increasing level of sulphur (Table 4.10). The superiority of S_1 and S_2 over S_0 in S-content of seed may be due to the sulphur applied as a nutrient through gypsum not only increased the availability of S from applied source but also the availability of native S of soil as reported by Dhillon and Dev (1980). Further, sulphur promotes the nodule formation on roots of legumes, which activate higher absorption of N and S from soil. The protein content (Table 4.10) was also significantly improved as nitrogen and sulphur increased in seed. The magnitude of increase was 17.07 and 21.05 per cent due to S_1 and S_2 over S_0. An increase in protein content obtained with sulphur (S_1 and S_2) was mainly owing to greater absorption of N and S by chickpea. Since both the nutrients are closely linked with protein metabolism and their relationship is synergistic (Aulakh and Pasricha, 1983), the increase in seed protein content is expected. Enhancement in the protein content may also be due to sulphur which play a vital role in nodulation (thereby the crop may receive more nitrogen) and protein synthesis, especially S-containing amino acids (methionine, cysteine and cystine) and finally it enters into protein structure. The results confirm the findings of Ram and Dwivedi (1992) and Kumar and Khangarot (2002).

5.5.4 Effect on post-harvest soil nutrient and soil moisture status

The data presented in the Table 4.11 and 4.12 indicated that application of sulphur did not show significant difference for post-harvest soil available N, P and K. Whereas, the available sulphur was observed significant higher under sulphur application than no sulphur application. This is might be due to the treatment effect.

Moisture content in soil recorded at flowering stage found significantly highest under 40 kg sulphur application. But moisture content determine at pod development stage (90 DAS) showed non-significant response of sulphur. Similar result was also observed by Joseph and Verma (1994).

5.6 INTERACTION EFFECTS

In a multifactor study three types of interaction viz., synergistic, antagonistic and no effect are expected. Therefore, instead of individual factor it is desirable to look for combined effect of different factors to derive maximum advantage of inputs. The interaction effects those found significant are discussed below.

5.6.1 Interaction of Irrigation x FYM

Interaction effect of irrigation x FYM on plant height (60 DAS) was found significant (Table 4.3). The treatment combination I_1F_1 recorded significantly the highest plant height (35.32), while significantly the lowest plant height (27.37) was recorded under treatment combination I_0F_0. This might be due to adequate moisture and nutrient present due to FYM under I_1F_1 treatment, which has provided congenial condition of water, and nutrient for favourable growth.

The irrigation × FYM interaction was found significant on number of nodule per plant (Table 4.6). The treatment combination I_1F_1 recorded significantly the highest number of nodule per plant (45.83), while significantly the lowest number of nodule per plant (35.75) was recorded under treatment combination I_0F_0. This might be due to the congenial condition of maximum growth of *Rhizobia* and root development of plant, which resulted in more number of nodules per plant.

As regards to effect of irrigation × FYM interaction (Table 4.14 and 4.15) with respect to moisture content in soil at flowering (50 DAS) and at pod development stage (90 DAS) the combination I_1F_1 produce higher moisture content at flowering (18.01 %) and at 90 DAS (12.77 %) than other treatment combinations, but the moisture content in soil at flowering stage was significantly improved by use of FYM even in presence of irrigation application or absence of irrigation at flowering stage. This might be due to organic manure (FYM) improve the physical condition of soil and assist the moisture holding capacity of soil.

5.6.2 Interaction of FYM × Sulphur

Moisture content in soil at pod development stage (90 DAS) was affected due to FYM × sulphur interaction. The treatment combination F_1S_1 recorded significantly higher moisture content (11.37 %) which was remaining at par with F_1S_0 (11.32 %) and F_1S_2 (11.13 %) treatment combinations. It clearly indicates that FYM with or without sulphur increase the moisture content in soil.

5.7 ECONOMICS

5.7.1 Effect of irrigation

Between two irrigation levels, I_1 (pre-sowing irrigation plus irrigation at flowering stage) recorded the highest net returns of Rs. 29094 per hectare with CBR of 1: 4.34 as compare to I_0 (only pre-sowing irrigation) of Rs. 23502 per hectare with CBR 1: 3.81. The increase in profitability was mainly due to higher grain yield (Table 4.17).

5.7.2 Effect of FYM

In case of FYM application, the treatment F_1 (10 t ha^{-1}) recorded the highest net realization of Rs. 27653 per hectare with CBR of 1: 3.98 than F_0 (0 t ha^{-1}) of Rs. 24919 with CBR of 1: 4.19. The increase in profitability was mainly due to higher grain yield (Table 4.17).

5.7.3 Effect of sulphur

Among various sulphur levels, S_3 (40 kg S ha^{-1}) recorded the highest net return of Rs. 27593 per hectare with CBR of 1: 4.20 followed by S_2 (40 kg S ha^{-1}) of Rs. 26596 per hectare with CBR 1: 4.11. The increase in profitability was mainly due to higher grain yield (Table 4.17).

5.7.4 Effect of interaction

Data given in Table 4.18 showed that treatment combination $I_1F_1S_2$ recorded the maximum net realization to the extent of Rs. 32441 ha^{-1} closely followed by treatment combination $I_1F_1S_1$ (Rs.30797 ha^{-1}) and $I_1F_1S_0$ (Rs.29009 ha^{-1}). The treatment combination $I_0F_0S_0$ recorded the lowest net realization of Rs. 20458 ha^{-1}. The higher monitory return under treatment combination $I_1F_1S_2$ was mainly on account of more yield and favourable response of chickpea to the irrigation, FYM and sulphur.

SUMMARY AND CONCLUSION

VI. SUMMARY AND CONCLUSIONS

The present investigation was carried out on sandy clay loam soil of Regional Sugarcane Research Station, Gujarat Agricultural University, Thasra. The study was conducted to evaluate the "Influence of irrigation, FYM and sulphur on growth, yield and quality of chickpea (*Cicer arientinum* L.) under middle Gujarat conditions" during *rabi* season of 2002-03.

The experiment was laid out in a split plot design with two irrigation levels (I_0: pre-sowing irrigation, I_1: pre-sowing irrigation + irrigation at flowing stage) and two FYM levels (F_0: 0, F_1: 10 tonnes ha^{-1}) relegated to main plot and three sulphur levels (S_0: 0, S_1: 20 and S_3: 40 kg S ha^{-1}) were assigned to sub plots. In all 12 treatment combinations were replicated four times. The recommended dose of NPK fertilizer (25:50:0 kg ha^{-1}) was administered as a basal application in all the treatments. The entire quantity of N and P_2O_5 were applied in the forms of urea and diammonium phosphate, respectively. The results, which have been presented and discussed in the preceding chapter, are summarized under the following headings.

I. Effect of irrigation

II. Effect of FYM

III. Effect of sulphur

IV. Interaction effect.

1. Effect of irrigation

Result revealed that plant population at harvest was not influenced by the irrigation.

Perusal of these data in general indicated that the maximum vegetative growth was achieved by application of two irrigations each at pre-sowing and at flowering stage (I_1).

Irrigation applied at pre-sowing plus at flowering stage had significantly increased plant height at 60 DAS and at harvest, whereas, at 30 DAS differences due to irrigation were non significant.

Number of branches per plant were also significantly improved due to application of one irrigation at pre-sowing and second at flowering stage (I_1) as compare to pre-sowing irrigation alone (I_0).

Similarly, number of nodules per plant and dry weight of nodules per plant were also increased with pre-sowing irrigation and one supplemental irrigation at flowering stage over pre-sowing irrigation only.

Among yield attributing characters, number of pods per plant, grain yield per plant and test weight were higher under I_1 irrigation level as compare to I_0. Harvest index was not markedly influenced by irrigation schedule.

Significantly the maximum grain yield was obtained under crop receiving pre-sowing irrigation in addition to irrigation at flowering stage (I_1). The magnitude of average increase in grain yield in I_1 was 359.78

kg ha^{-1} over that of I_0. The irrigation schedule I_1 further significantly recorded higher straw yield over I_0.

The quality parameters like nitrogen, protein and sulphur contents in grain were obtained significantly higher under I_1 than I_0.

The post harvest available soil nutrients like N, K_20 and S were remained unaffected due to irrigation schedule, while post harvest available P_20_5 was significantly higher under I_1.

Moisture content in soil at flowering stage (50 DAS) and at pod development (90 DAS) was observed higher under pre-sowing and pre-sowing plus irrigation at flowering stage.

Between two irrigation levels, I_1 (pre-sowing and at flowering stage) recorded the highest net return of Rs.29094 per hectare with CBR of 1:4.34 as compare to I_0 (only pre-sowing irrigation) with net realization Rs.23502 per hectare and CBR of 1:3.81.

2. Effect of FYM

Plant population at harvest was not influenced by application of FYM.

FYM application significantly improved the plant height at 60 DAS, however, at 30 DAS and at harvest though the FYM application had numerically increased the plant height.

Number of branches per plant was observed higher under application of FYM @ 10 tonnes ha^{-1} than no FYM.

The differences in number of nodules per plant and dry weight of nodules per plant were significantly increased due to application of FYM (@ 10 tonnes ha^{-1}).

Application of FYM @ 10 tonnes ha^{-1} produced significantly higher yield attributes such as number of pods per plant, grain yield per plant, grain and straw yields and test weight than no application of FYM. The harvest index showed non-significant results with FYM application.

The quality parameters like nitrogen and protein contents in grain were also improved significantly by FYM application but sulphur content in grain showed non-significant results with FYM application.

Further, application of FYM tended to increase the post harvest available soil nitrogen and phosphorus significantly. Available soil potassium and sulphur content did not differ significantly due to FYM application.

Moisture content in soil at flowering (50 DAS) and at pod development stage (90 DAS) was significantly more under FYM application.

Between two FYM levels, F_1 (@ 10 tonnes ha^{-1}) recorded the highest net return of Rs.27653 per hectare with CBR of 1:3.98 than F_0 (0 tonnes ha^{-1}) with net realization of Rs.24919 per hectare and CBR of 1:4.19.

3. Effect of sulphur

Results indicated that plant population (at harvest) of chickpea was not significantly altered due to application of sulphur.

Application of sulphur @ 40 kg S ha^{-1} produced significantly the higher plant height, number of nodules per plant and dry weight of nodules per plant than sulphur applied @ 20 and 0 kg S ha^{-1}.

Treatment S_2 (40 kg S ha^{-1}) being at par with S_1 (20 kg S ha^{-1}) recorded significantly higher number of branches per plant over 0 kg S ha^{-1}.

Application of sulphur either @ 40 or 20 kg S ha^{-1} significantly increased the yield attributes such as number of pods per plant, grain yield per plant and test weight as well as grain and straw yields.

Variation in harvest index due to sulphur treatment was absent.

Application of sulphur @ 40 kg S ha^{-1} recorded significantly higher nitrogen, protein and sulphur contents in grain over 20 and 0 kg S ha^{-1}.

Difference in post harvest available soil nutrients like N, P_20_5 and K_20 were not large due to sulphur application. While, the post harvest sulphur content was significantly higher under 20 kg S ha^{-1} than 0 kg S ha^{-1} but the former was at par with 40 kg S ha^{-1}.

Similarly, moisture content in soil at flowering stage (50 DAS) recorded significantly higher under 40 kg S ha^{-1} over 20 and 0 kg S ha^{-1}, while, at pod development stage (90 DAS) it was remained unaffected due to sulphur treatment.

Among various sulphur levels, S_2 (40 kg S ha^{-1}) recorded the highest net return of Rs.27593 per hectare with CBR 1:4.20 followed by S_1 (20 kg S ha^{-1}) with net realization Rs. 26596 per hectare and CBR of 1:4.11.

4. Interaction effect

(i) Interaction I × F

The interaction I × F exhibited significant effect on plant height at 60 DAS wherein treatment combination I_1F_1 (Irrigation at pre-sowing + flowering stage along with 10 tonnes FYM ha^{-1}) produced maximum plant height (35.32 cm) at 60 DAS over rest of the combinations.

Similarly, this treatment combination (I_1 × F_1) also showed its superiority over rest of all other combinations in case of number of nodules per plant, moisture content in soil at flowering and pod development stages.

***(ii)* Interaction F × S**

Interaction F × S recorded significantly highest moisture content in soil at pod development stage (90 DAS). Treatment combination F_1S_1 (10 tonnes FYM ha^{-1}, 20 kg S ha^{-1}) produced higher moisture percent (11.37) in soil at 90 DAS.

CONCLUSION

In view of results obtained from the present investigation it could be concluded that

1. Application of irrigation one at pre-sowing and second at flowering stage produced higher grain and straw yields and realized maximum net return of Rs.29094 per hectare.
2. Application of FYM @ 10 tonnes ha^{-1} were produced more grain and straw yields and realized higher net return.
3. Among different sulphur treatments application of sulphur @ 40 and 20 kg S ha^{-1} were produced more or less same yield but the net return was secured higher with the application of 40 kg S ha^{-1}.
4. In case of treatment combination of two irrigations each applied at pre-sowing and flowering stage, application of FYM @ 10 tonnes ha^{-1} and application of sulphur @ 40 kg S ha^{-1} produced maximum grain (2567 kg ha^{-1}) and straw (3579 kg ha^{-1}) yields and realized the highest net profit of Rs.32441 per hectare.

From the yields and economic point of view, it is concluded that for securing higher yield and net return, the chickpea crop should be irrigated twice at pre sowing and at flowering stage, application of

FYM @ 10 tones ha^{-1} and application of sulphur @ 40 kg S ha^{-1} under sandy clay loam soil of middle Gujarat Agro-climatic conditions.

FITURE LINE OF WORK

The following suggestions are made for future line of work on the basis of the results obtained from the present investigations.

1. To obtained valid conclusion, the study should be repeated at least for one more season.
2. Such studies should be conducted under different Agro-climatic conditions on different type of soils.
3. A long-term experiment consisting organic manures and fertilizers need to be conducted to know the residual effects on succeeding crop and also for their effects on physico-chemical and biological properties of soil.
4. More study is required to derive the best-suited combination of irrigation, FYM and sulphur for getting maximum returns from Cv. ICCC-4 of chickpea under middle Gujarat Agro-climatic conditions.

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* Original not seen

APPENDICES

Appendix I

Appendix : Cost of cultivation of chickpea and other d^etails of cost incurred

(A) Details of operation cost

Sr. No.			Particular	Cost (Rs ha^{-1})
(A)			Seed (60 kg ha^{-1}@ RS. 30 kg^{-1}	1800
(B)			Land preparation	
	(1)		Tractor cultivation (3 hr. @ RS. 60 hr^{-1})	180
	(2)		Harrowing and planking (2 PB, 2 M)	250
(C)			Sowing	
	(1)		Opening of furrow for fertilizer application and planking (2 PB, 2 M)	250
	(2)		Preparation of beds and irrigation channels (1 PB, 4 M)	275
	(3)		Cost of fertilizers	
		(i)	Nitrogen (From urea @ Rs.11.33 kg^{-1} and from DAP @ Rs.15.86 kg^{-1})	347
		(ii)	Phosphorus (From DAP @ Rs 15.83 kg^{-1})	728
	(4)		Cost of sowing (1 PB, 2 M)	175
(D)			After care	
	(1)		Gap filling and thinning (3 M)	150
	(2)		Interculturing one time (1 PB, 2 M)	175
	(3)		Hand weeding two time (10 M)	500
	(4)		Plant protection (2 M) (Endosulphan 0.07 % @ 1 lit. ha^{-1}, Rs 260 lit. $^{-1}$)	426
(E)			Harvesting (8 M)	400
(F)			Threshing and winnowing (12 M)	600
(G)			Land revenue	50
			TOTAL	**6306**

Note: The total cost is carried over in appendix II (C) column No. 4

PB: Pair bullock @ Rs. 75 day^{-1}

M: Man @ Rs. 50 day^{-1}

W: Women @ Rs. 50 day^{-1}

Skill labour @ Rs. 83 day^{-1}

(B) Details of cost of irrigation, FYM and sulphur and fertilizer

Treatment	Number/quantity Required (ha^{-1})	Cost (Rs.)	Application charges (Rs ha^{-1})	Total cost of treatments (Rs ha^{-1})
(A) Irrigation schedule (I)				
I_0	1	200	100	300
I_1	2	400	200	600
(B) FYM (F)				
F_0	0 tone	-----	------	------
F_1	10 tone	125	50	1300
(C) Sulphur (S)				
S_0	0 kg sulphur	-----	------	------
S_1	20 kg sulphur	50	50	100
S_2	40 kg sulphur	100	50	150

Note: 1. 25 kg N ha^{-1} and 50 kg P2O5 ha^{-1} was applied uniformly to all the plots as basal dose

2. The cost of treatment are mentioned in appendix-C column 2 and 3
3. Irrigation required 10 hrs ha^{-1} @ Rs. 20 hr^{-1}
4. FYM @ Rs.125 $tonne^{-1}$
5. Sulphur @ Rs. 2.50 kg^{-1} from gypsum

(C) Total cost incurred for different treatment combinations

Sr. No.	Treatment combi-nations	Irrigation cost (Rs ha^{-1})	Fertilizer cost (i.e. FYM, Sulphur) Rs ha^{-1}	Cost of seed + Cost of cultivation (Rs ha^{-1})	Interest on @ 12% for 4 months (Rs ha^{-1})	Supervision charges 2+3+4 @ 10% (Rs ha^{-1})	Total cost of cultivation (Rs ha^{-1})
	1	2	3	4	5	6	7
1	$I_0F_0S_0$	300	0.0	6306	264	661	7531
2	$I_0F_0S_1$	300	100	6306	268	671	7645
3	$I_0F_0S_2$	300	150	6306	270	676	7702
4	$I_0F_1S_0$	300	1300	6306	316	791	9013
5	$I_0F_1S_1$	300	1400	6306	320	801	9127
6	$I_0F_1S_2$	300	1450	6306	322	806	9184
7	$I_1F_0S_0$	600	0.0	6306	276	691	7873
8	$I_1F_0S_1$	600	100	6306	280	701	7987
9	$I_1F_0S_2$	600	150	6306	282	706	8044
10	$I_1F_1S_0$	600	1300	6306	328	821	9355
11	$I_1F_1S_1$	600	1400	6306	332	831	9469
12	$I_1F_1S_2$	600	1450	6306	334	836	9526

APPENDIX-II

Analysis for variance for growth parameters, yield attributes, yield and quality parameters and post harvest available nutrients

Mean sum of square for

Source of variance	df	Plant population at harvest	Plant height at 30 DAS (cm)	Plant height at 60 DAS (cm)	Plant height at harvest (cm)	No. of branches per plant	No. of nodules per plant	Dry weight of nodules per plant (mg)	No. of pods per plant	Grain yield per plant (g)	Grain yield (kg ha^{-1})
Replication	3	0.175	7.147	0.897	31.299	5.850	1.464	255.800	1182.850	39.951	2868123.000
I	1	1.947	0.242	462.507	38.002	5.200	728.518	109718.600	3407.143	160.603	1553259.000
F	1	1.939	5.469	36.387	16.002	7.840	63.018	5620.962	1958.480	100.343	796882.000
I × F	1	0.190	0.002	8.183	-0.023	2.708	15.190	460.982	530.595	5.465	18358.080
Error (a)	9	0.933	1.479	0.598	5.453	0.926	2.817	311.445	211.753	10.244	81225.130
S	2	0.016	1.121	54.669	3.135	5.657	85.582	46953.900	543.321	36.267	146658.700
I × S	2	0.666	0.200	1.168	0.701	0.216	0.585	180.078	4.407	0.060	5218.611
F × S	2	0.044	1.042	0.733	1.346	0.306	0.585	90.049	8.931	1.140	3009.478
I × F × S	2	0.966	0.782	0.220	1.628	0.187	0.249	76.238	9.126	0.544	2868.310
Error (b)	24	1.215	1.013	0.962	7.541	0.919	0.667	134.980	157.903	6.101	31991.820

Contd....

Mean sum of square for

Straw yield (kg ha^{-1})	Test weight (g)	Harvest index (%)	Nitrogen content in grain (%)	Protein content in grain (%)	Sulphur content in grain (%)	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})	Available S (kg ha^{-1})	Moisture % at flowering	Moistu % at 9 DAS
2333961.000	61.771	51.210	0.006	0.251	0.000008	210.250	0.944	2164.306	4.269	1.320	2.7
4559202.000	655.843	18.669	1.568	61.254	0.003	13.042	720.750	875.542	0.827	2.845	134.3
1323656.000	27.806	0.739	0.082	3.214	0.00004	10950.540	208.333	25.542	0.609	66.395	14.2
28244.260	8.006	0.095	0.00001	0.003	0.000008	88.000	0.750	540.000	5.431	2.364	1.4
70183.020	116.476	4.330	0.011	0.437	0.00002	1828.759	6.074	4824.815	5.238	0.191	0.0
414872.500	241.460	1.576	1.402	54.759	0.034	523.531	3.938	879.531	289.399	0.947	0.0
4421.359	20.574	0.217	0.005	0.176	0.000007	2319.261	110.438	344.760	1.351	0.044	0.0
9812.747	0.361	0.290	0.003	0.108	0.000007	4147.385	44.146	1980.885	11.406	0.201	0.6
5124.723	3.810	0.290	0.001	0.045	0.0001	1184.906	34.563	3572.406	17.796	0.128	0.1
41104.810	68.576	1.612	0.006	0.237	0.00025	2332.465	5.771	1704.063	42.321	0.158	0.0