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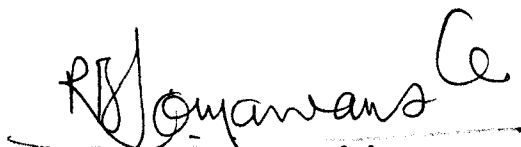
EFFECTS OF GYPSUM, FERROUS SULPHATE AND QUALITY
OF IRRIGATION WATER ON CHLOROSIS AND GROWTH
OF SUGARCANE (Saccharum officinarum)

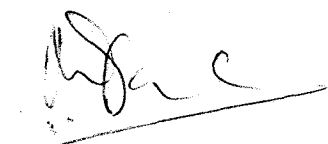
by
V.M. PATIL


A Thesis submitted in partial fulfilment of the
requirements for
the degree
of

MASTER OF SCIENCE (AGRICULTURE)
in
SOIL SCIENCE

Approved


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MAHATMA PHULE AGRICULTURAL UNIVERSITY
RAHURI 413 722
Phule Nagar,

1983

CANDIDATE'S DECLARATION

I hereby declare that the thesis or part thereof has not been
submitted by me or other person to any other University
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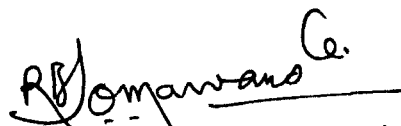
CERTIFICATE

This is to certify that the thesis entitled "Effects of gypsum, ferrous sulphate and quality of irrigation water on chlorosis and growth of sugarcane (Saccharum officinarum)", submitted to the Mahatma Phule Agricultural University, Rahuri for the award of the Degree of Master of Science in Soil Science, embodies the results of a bona fide research work carried out by Shri V.M. Patil, under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

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Dated : 23.11.1983


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Dated :

21/1/87


(B.H. Mogal)

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Lastly, I express my heartfelt gratitude to my parents who built up my educational career.

Rahuri,

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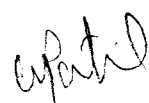

V.M. Patil

TABLE OF CONTENTS

	CANDIDATE'S DECLARATION	11
	CERTIFICATES	
	(i) Research Guide	111
	(ii) Associate Dean (PGI) ..	iv
	ACKNOWLEDGEMENTS	v
	LIST OF TABLES	viii
	LIST OF FIGURES	x
	LIST OF PLATES	x
	ABSTRACT	xi
1	INTRODUCTION	1
2	REVIEW OF LITERATURE	3
	2.1 Effects of Salinity on Soil Properties, Plant Growth, Chlorophyll Content and Root Growth	4
	2.1.1 Soil properties	4
	2.1.2 Plant growth	10
	2.1.3 Chlorophyll content	12
	2.1.4 Root growth	13
	2.2 Effect of Gypsum on Soil Properties and Plant Growth	14
	2.3 Effect of Ferrous Sulphate on Iron Availability and Plant Growth	16
	2.4 Relationship Between Plant Iron and Chlorophyll	19
3	MATERIAL, METHODS AND EXPERIMENTAL	22
	3.1 Material	22
	3.1.1 Soil	22
	3.1.2 Irrigation water	22
	3.1.3 Crop	23
	3.2 Methods	23
	3.2.1 Analysis of soil and irrigation water	23
	3.2.2 Plant analysis	25
	3.2.3 Statistical method	25

TABLE OF CONTENTS
(Contd.....)

3.3	Experimental	26
3.3.1	Pot culture experiment	26
3.3.2	Treatment details	26
3.3.3	Quantity of amendments used	27
3.3.4	Harvesting	28
3.3.5	Root study	28
4	RESULTS AND DISCUSSION	29
4.1	Analysis of DTPA-Extractable Fe and Mn, pH and Exchangeable bases of Soil	29
4.1.1	DTPA-Fe and Mn	29
4.1.2	EC and pH of soil	30
4.1.3	Exchangeable bases	31
4.2	Plant Studies	32
4.2.1	Total leaf-Fe	32
4.2.2	Total leaf-Mn	33
4.2.3	Leaf Ca and Mg	34
4.2.4	Leaf N and P	34
4.2.5	o-Ph extractable leaf-Fe	36
4.2.6	Chlorophyll content	39
4.2.7	Root composition	39
4.2.8	Dry matter yield of sugarcane tops and roots	42
5	SUMMARY AND CONCLUSION	48
5.1	Soil Studies	48
5.2	Plant Studies	49
6	LITERATURE CITED	52
7	VITA	60

LIST OF TABLES

<u>Table</u>	<u>Page</u>
1	Physical and chemical properties of the soil 22
2	Properties of soil, saturation extract and well water 23
3	Methods used for analysis of soil and irrigation water 24
4	Methods used for plant analysis 25
5	Basal application of N, P, K, Cu, Zn, Mo and B 26
6	The details of the treatments 26
7	Quantity of gypsum and ferrous sulphate added per pot 27
8	Effects of gypsum, ferrous sulphate and quality of irrigation water on periodical DTPA-Fe and Mn content of soil 29
9	Effects of gypsum, ferrous sulphate and quality of irrigation water on pH and EC of soil (1:2.5) on 160 days growth of sugarcane 31
10	Effects of gypsum, ferrous sulphate and quality of irrigation water on exchangeable bases of soil on the 160 days growth of sugarcane 32
11	Periodical composition of leaf Fe and Mn of sugarcane as affected by gypsum, ferrous sulphate and quality of irrigation water 33
12	Effects of gypsum, ferrous sulphate and quality of irrigation water on the periodical Ca and Mg contents of 3rd leaf of sugarcane 34
13	Effects of gypsum, ferrous sulphate and quality of irrigation water on the leaf-N and P contents of sugarcane leaf 35

LIST OF TABLES
(Contd.....)

<u>Table</u>		<u>Page</u>
14	Periodical composition of o-Ph leaf-Fe and chlorophyll of sugarcane as affected by gypsum, ferrous sulphate and irrigation water	37
15	Effects of gypsum, ferrous sulphate and quality of irrigation water on the composition of sugarcane roots	41
16	Effects of gypsum, ferrous sulphate and quality of irrigation water on dry matter yield of sugarcane tops and roots	42
17	Correlation coefficients (r) between soil and plant parameters at two periods of sugarcane growth	45

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
1 Periodical analysis of leaf-Fe ²⁺ as affected by application of gypsum and ferrous sulphate ..	38
2 Periodical analysis of total chlorophyll as affected by application of gypsum and ferrous sulphate	40
3 Dry matter yield of sugarcane tops as affected by application of gypsum and ferrous sulphate....	43
4 Dry matter yield of sugarcane roots as affected by application of gypsum and ferrous sulphate ...	44

PLATE

- 1 Effect of gypsum, ferrous sulphate and quality
 of irrigation water on root growth of sugarcane. 46

EFFECTS OF GYPSUM, FERROUS SULPHATE AND QUALITY
OF IRRIGATION WATER ON CHLOROSIS AND GROWTH
OF SUGARCANE (Saccharum officinarum)

by
V.M. Patil

A candidate for M.Sc. (Agri.)

Research Guide	:	Dr. R.B. Somawanshi
Discipline	:	Soil Science
Department	:	Agril. Chemistry & Soil Science

A pot culture experiment was conducted in the greenhouse to study the effect of gypsum, ferrous sulphate and quality of irrigation water on chlorosis and growth of sugarcane (Cv.CO-740). The experiment was conducted at Post-Graduate Institute, M P A U, Rahuri.

The DTPA-Fe of soil was significantly increased due to the application of ferrous sulphate. There was significant increase in the exchangeable Ca and decrease in exchangeable Mg of soil irrigated with distilled water. The reverse trend was observed with well water which contained more Mg concentration compared to Ca ions. Sugarcane leaves relatively chlorotic from the control and gypsum treatments contained maximum concentration of nitrogen, when compared to other treatments. Total leaf-Fe concentration was not influenced by gypsum and ferrous sulphate treatments.

Application of ferrous sulphate alone or in combination with gypsum increased chlorophyll and orthophenanthroline extractable leaf-Fe (o-Ph leaf-Fe) content. Leaf chlorophyll was strongly and positively correlated with o-Ph leaf-Fe ($r=0.545$) observed on the 160th day of sugarcane growth. The use of saline irrigation water resulted in the significant decrease in Ca and increase in Mg content of roots.

Application of ferrous sulphate with and without gypsum and without consideration of quality of irrigation water resulted in a significant increase in the dry matter of tops and roots as compared to that in the control. The quality of water did not make any difference on the sugarcane growth.

The study suggests that chlorotic condition of sugarcane crop could be improved by removing iron stress through mixing ferrous sulphate with saline soil, as was evidenced by higher DTPA-Fe of soil, o-Ph leaf-Fe and chlorophyll which resulted in the higher dry matter production.

Chapter Opener Page

INTRODUCTION

1. INTRODUCTION

Symptoms of chlorosis in sugarcane are quite common these days, wherever this crop is grown on saline calcareous soils of Maharashtra. Over one-third of the world's land is calcareous, which is one of the common causes for chlorosis in several crops. Other cause of chlorosis is the deficiency of iron in soil (Brown, 1961). The problem of sugarcane chlorosis in Maharashtra is serious particularly on naturally well drained sandy loam calcareous saline soils on the banks of the several rivers which results in decrease in the sugarcane yield.

Salinity and chlorosis are observed to be the most important factors for reduction in the yield of sugarcane in Rahuri tehsil of Ahmednagar District. The sugarcane cv. Co-740 shows severe chlorosis right from emergence up to maturity (Sanas, 1983). Initially, interveinal portion of upper green leaves turns light green, then becomes yellow followed by yellowing of veins and turning the entire leaf white and then brown before it dies.

The length of internode is occasionally as less as 2.5 to 3.0 cm with hard nodes. The root growth is limited and most of the roots turn brown to dark black. Roots near soil surface look tender, white and active. They are very short and less in number. Well water used for irrigation is highly saline wherein calcium, magnesium, chloride and sulphate are the predominant ions. The continuous use of this water has

turned these soils saline, although they are inherently well drained.

High levels of calcium carbonate (Tandon and Srivastava, 1981), and salinity (Joshi and Naik, 1977) in soils have been reported to induce chlorosis and reduce vigour and growth of sugarcane. Almost all the soils from semi-arid tract of Maharashtra are more or less calcareous and saline, but do not show chlorosis at all. The soils on the banks of Mula and Pravara rivers are also calcareous and saline showing severe chlorosis in sugarcane. Although severity of the problem in the region and economic losses due to chlorosis are not estimated, some fields with severe chlorosis have resulted in the failure of crop even on highly fertile soils.

A study was, therefore, undertaken to assess, if the use of gypsum and ferrous sulphate with or without saline irrigation water, would increase the chlorophyll and o-Phenanthroline extractable leaf-Fe contents of sugarcane leaves and thereby promoting plant growth and yield of sugarcane crop.

Chapter Opener Page

R E V I E W O F
L I T E R A T U R E

2. REVIEW OF LITERATURE

The present experiment was based on the conditions prevailing in the area of Rahuri, where sugarcane crop is grown on light textured and well drained saline calcareous soils containing more of Mg^{2+} and Ca^{2+} salts. Well-water used for sugarcane is also highly saline. Chlorides and sulphates are the principal anions. Farmers of this region have been sustaining problems of soil salinity. The problem of chlorosis seems to have aggravated when underground water (well-water) contained high proportion of soluble Ca and Mg salts despite high soil fertility (Pharande, 1982). Tisdale and Nelson (1966) proposed that iron deficiency or chlorosis is caused due to imbalances of metallic ions such as copper and manganese, excessive amounts of phosphate in soil, combination of high pH, high lime, high soil moisture, low temperature and high levels of HCO_3^- in the root zone. Sugarcane grown in the Ahmednagar District of Maharashtra is showing extensive chlorosis which is expanding every year. The pertinent literature on which the present investigation is based, is reviewed under different headings viz.,

- 2.1 Effects of Salinity on Soil Properties, Plant Growth, Chlorophyll Content and Root Growth.
- 2.2 Effect of Gypsum on Soil Properties and Plant Growth.
- 2.3 Effect of Ferrous Sulphate on Iron Availability and Plant Growth.
- 2.4 Relationship Between Plant Iron and Chlorophyll.

2.1 Effects of Salinity on Soil Properties, Plant Growth, Chlorophyll Content and Root Growth

2.1.1 Soil properties

Kelly et al. (1940) showed that relatively more Na^+ would be adsorbed on Mg^{2+} saturated soil, if Mg^{2+} constituted a relatively high proportion of total exchange of soil. They reported that high amount of Mg^{2+} in irrigation water and also in soil solution which would result in high exchangeable Mg^{2+} in soil, would be detrimental to crop growth because physical effect of exchangeable Mg^{2+} is more nearly like that of Na^+ rather than that of Ca^{2+} .

Prince et al. (1947) reported that the ideal amount of Mg^{2+} would be 10 per cent of the total exchange capacity of the soil. Jones (1950) concluded that toxic effect of Mg^{2+} was observed when MgO/CaO ratio exceeded 1.0. It might be due to the formation of $\text{Mg}(\text{HCO}_3)_2$ and thereby rise in soil pH.

Bonnet (1953) reported that the excess salts in saline and saline alkali soils could be leached out with fresh water after the addition of gypsum. It carried salts below the root zone of penetration and thus improved the growing condition. Soil might be reclaimed by leaching with water if good drainage was provided. Removal of excess salts from the surface soil results in much greater efficiency of canes and top growth.

Budanov (1954) found that application of 840 kg/ha of calcium sulphate to a highly saline Chestnut soil with the water table at 6 meters increased the yield of winter wheat by 40 per cent and decreased exchangeable sodium from 9.67 to 1.62 meq and the salt content from 155.8 to 56.8 meq in 100 g of soil.

Amemiya et al. (1956) found that the amounts of soluble salts and exchangeable sodium in the soil were materially decreased by leaching. This decrease was a function of the amount of water used to leach the soil. Gypsum application in combination with leaching had little or no effect on reducing exchangeable sodium. There were indications that salts and exchangeable sodium might be reaccumulative in the profile.

Heimann (1959) considered exchangeable Mg^{2+} as harmful as Na^+ while K^+ as harmless as Ca^{2+} . Allison (1964) stated that Ca^{2+} and Mg^{2+} found in normal soils of arid region, were not dominant cations. However, as soluble salts accumulated from irrigated waters become more concentrated in the soil due to lack of leaching and continuous irrigation, certain composition changes were observed. The solubility limits of $CaSO_4$, $CaCO_3$ and $MgCO_3$ were exceeded causing $Ca^{2+} + Mg^{2+}$ to precipitate in soil. This caused a corresponding increase in the relative proportion of Na^+ in the soil solution.

Misra (1961) studied the effect of leaching of soils

with divalent cations and observed that soil exchangeable complex became enriched with respect to divalent cations, as compared to monovalent cations which was greatly reduced. The leaching resulted in the fall in pH of alkali soils after leaching the soil with dilute solution of CaCl_2 , MgCl_2 and CaSO_4 . The normal soils, however, showed no effect on exchange complex but only exchangeable Mg^{2+} increased as a result of leaching with dilute solution of MgCl_2 .

Shriramamurthy (1961) conducted a leaching trial with saline alkali soils and studied the effect of leaching and cropping on certain soil characteristics. Leaching of the soil (Ec 7.6, pH 8.7) without addition of any amendment decreased total soluble salts content, but increased the pH, soluble Na^+ and Mg^{2+} when leached with amendment, soluble salts as well as pH, both decreased.

Kelley (1964) found that the most important effect of saline irrigation water was cation exchange where Ca^{2+} was replaced by Na^+ , but this exchange would not ordinarily be excessive if the Ca^{2+} content of the water was 35 or more percentage of the total cations of the applied water. pH could be controlled by proper choice of irrigation water.

Lunin et al. (1964) studied that soil salinity increased such that Ec of saturation extract reached 15.4 mmho/cm as a result of saline irrigation. The Ca^{2+} , Mg^{2+}

and K^+ content increased with increasing salinity. Exchangeable Ca^+ in the soil decreased and Mg^{2+} , Na^+ and K^+ increased with increasing salt concentration of water applied.

Moghe and Bokare (1965) studied the effect of leaching saline-alkali soils with different quality of waters and concluded that leaching soils with normal or alkaline water removed salts more efficiently, than did leaching with saline-alkaline or saline water. Normal and saline soils, but not saline alkaline and alkaline soils, increased pH when leached with saline-alkaline and alkaline water. Leaching increased ESP of soils, but this increase was reduced when the soils were pyritized with gypsum.

Gupta and Abichandani (1968) used salt waters predominant in divalent cations for irrigation in the semi-arid zone of Western Rajasthan and concluded that irrigation with highly saline water predominant in divalent cations resulted in accumulation of soluble salts in deep sandy to sandy loam soil, but pH and the concentration of soluble and exchangeable Na^+ were not of harmful amount in the root zone of the soils. The SAR and per cent exchangeable Na^+ of irrigated soil were low and availability of dissolved Ca^{2+} and Mg^{2+} was high.

Misra et al. (1969) observed that repeated leaching of saline-alkali and alkali soils was performed with distilled water under laboratory conditions. In spite of high contents of $CaCO_3$ in last two profiles, the alkalinity of the soil did

not decrease hence sufficient Ca could not be brought into solution during the course of leaching. However, saline soil due to the low alkalinity and less exchangeable sodium responded well to leaching, even it contained less of CaCO_3 . Variation in soil-water ratio produced marked influence on the soluble CO_3 , HCO_3 and other soluble salts as affected by repeated leaching.

Patel and Dastane (1971) observed the leaching up to 10 per cent was favourable when saline irrigation was given at a later stage of crop growth. There was decrease in salt accumulation as the texture became lighter which might be a long term advantage.

Panov and Adda (1972) studied the role of exchangeable Mg^{2+} in the development of solonetz process of soil formation and observed that the effects of Mg^{2+} on physical and chemical process of soil were intermediate between those of Ca^{2+} and Na^+ . Effects of Mg^{2+} were similar to those of Na^+ in increasing the proportion of exchangeable Mg^{2+} when proportion of Na^+ was constant. Excess Mg^{2+} increased the dispersion, swelling and maximum hygroscopicity of soil, but decreased infiltration and capillary raise.

Prasad (1973) showed that there were evidences that crops suffer from Ca^{2+} deficiency in soils irrigated with waters having high proportion of Mg^{2+} in relation to Ca^{2+} . The hazardous effect of Mg^{2+} in highly saline water was

aggravated being associated with Na^+ and in low saline water by virtue of its predominant nature over Na^+ , and insufficiency of Ca^{2+} further increased the hazardous effect of water on soil properties and crop growth.

Mathur et al. (1973) flooded two basins with a measured quantity of water, one of the basins was treated with gypsum at the rate of 15 t/ha while the second was without gypsum. They emphasized that leaching caused reduction in electrical conductivity, increase in pH and decrease in exchangeable Na per cent with gypsum application.

Bhumbla (1977) found that most of waters in arid areas have high salinity hazard, but usually have low Na hazard. The same water used for irrigation had $\text{EC} > 10,000$ mmho/cm. The relative proportion of Na^+ , Mg^{2+} and Cl^- increased with increasing salt content. Generally Mg^{2+} is more than Ca. In clay and clay loam soils water with salt content of more than 2,000 mmho/cm proved hazardous.

Yadav and Girdhar (1980) studied the effect of irrigation water having varying Mg/Ca ratio (2, 4, 8 and 16) and electrolyte concentration (20 and 80 meq/L) on soil properties and plant growth of wheat crop in two different soils. They observed that salinity was at greater magnitude in heavy textured black soil dominated by montmorillonite clay mineral than in the light textured alluvial soil having illite type of clay mineral. The accumulation of soluble

salts as a result saline irrigation water was higher in the surface layer than in subsurface layer. The adsorption of Na and Mg in the soils increased with an increase in Mg/Ca ratio and electrolyte concentration of the irrigation water. Behaviour of Mg is different from that of Ca in affecting soil properties and plant growth.

Singh et al. (1980) studied the effects of different concentrations of gypsum solutions on sodic soils. They investigated the effects of leaching two artificially prepared sodic soils, one rich in chloride and other in bicarbonate ions with gypsum solutions, under the laboratory scale. The soils packed in acrylic columns were leached with gypsum solutions of three different concentrations, keeping the total amount of gypsum same in all treatments. A greater decline in ESP and pH was observed with decrease in Ca concentration, than any other treatment in carbonate treated soil. In chloride treated soil, its effect was equivalent to leaching with 20 cm solution of 30 meq/L concentration. The decrease in EC was the function of total amount of solution/water passing through the column in both the soils.

2.1.2 Plant growth

Key et al. (1961) studied the influence of ratio of exchangeable Ca^{2+} and Mg^{2+} on yield and composition of soya-bean and corn. Poor growth was observed when $\text{Ca}^{2+}:\text{Mg}^{2+}$ ratio was less than one. In sand and resin cultures, no

effect of $\text{Ca}^{2+}:\text{Mg}^{2+}$ ratio was found when Ca^{2+} exceeded Mg^{2+} . Differences in growth were associated with the amount of these ions rather than their ratio.

Bernstein et al. (1966) showed that CO-740 variety of sugarcane was not salt tolerant. Yield and growth reduction occurred up to 50 per cent at 3.3 mmho/cm specific conductance.

Deo and Kanwar (1968) found that the increasing SAR values of irrigation water decreased the plant growth. In presence of single dominant cation the growth decreased as $\text{K} > \text{Mg} > \text{Na} > \text{Ca}$. The increase of Na in proportion to Ca, Mg or K decreased the yield and decrease was in order : $\text{K} > \text{Mg} > \text{Ca}$. Potassium in irrigation water even at low concentration with Mg was more harmful than with Ca. In case of calcium rich water, Ca content of the plant increased and Na content decreased, but K content was not much affected. When sodium and potassium rich waters were used, the Na and K content increased manifold and Ca content decreased. The uptake of Na was less in Na:Ca system than in Na:Mg system. Potassium in irrigation was found to restrict the absorption of Na by plant.

Clark (1975) studied the differential Mg^{2+} efficiency of corn inbred with different Mg^{2+} levels on dry matter production and mineral composition of plant. Corn plant grew better at low Mg^{2+} concentration level, produced maximum dry

matter due to lower concentration of Mg^{2+} in roots over higher Mg^{2+} level in roots. Various essential mineral elements in the roots viz., P, Mn, Fe, Cu and Mo and leaf concentration of Ca^{2+} , P, Mn, Zn, B and Cu decreased more with the increase in Mg^{2+} concentration.

Prasad and Paliwal (1976) studied the effect of gypsum on the growth of wheat irrigated with Mg^{2+} rich water and observed that the yield of wheat decreased, with increase in the $Mg^{2+}:Ca^{2+}$ ratio. When gypsum was applied to soil in the saturated solution form, the dry matter and grain yield increased significantly beyond 4:1 $Mg^{2+}:Ca^{2+}$ ratio. They also reported that gypsum gave better results when it was applied in irrigation water, than when applied through soil. On gypsum application increased in $Ca^{2+}:Mg^{2+}$ ratio in irrigation water and $Ca^{2+}:Na^+$ ratio in exchangeable complex appeared to be responsive for better crop growth.

2.1.3 Chlorophyll content

Kanwar and Ehumbla (1961) studied the different water tables and salinity levels on chlorophyll content of leaves of sweet orange and observed that the chlorophyll content of leaves decreased as the level of salinity increased and the water table decreased. The decrease in the chlorophyll content of the leaves with low water table of 30 cm could be attributed to the reduction in the Ca^{2+} , Mn^{2+} , Zn^{2+} , Fe^{2+} and increase in the uptake of K^+ and Na^+ .

Joshi and Naik (1977) tested sugarcane (Cv. CO-740) for its salt tolerance and photosynthetic productivity and concluded that there was stimulatory and deleterious effect of NaCl and Na₂SO₄ salts on total photosynthetic area. The increase in concentration of NaCl and Na₂SO₄ decreased the chlorophyll content of sugarcane leaves except at 0.05 M NaCl level, where stimulatory effect in chlorophyll synthesis at lower concentration of NaCl was observed (Nimbalkar and Joshi, 1975 and Karmarkar and Joshi, 1969).

Siddique (1980) studied in pot culture the effect of salinization and desalinization on chlorophyll content of leaves of pea, showed that chlorophyll content of leaves was reduced progressively with increase in salinity. Desalinization causes recovery in chlorophyll content of first fully expanded leaf. Desalinization drastically reduced the Na⁺ and Cl⁻ content of plant organ. Increase in salinity reduced the dry weight, number of pods and seeds.

2.1.4 Root growth

Karataev and Mamalva (1958) observed that root growth progressively impeded when Mg²⁺ saturation exceeded 40 to 60 per cent of the exchange capacity. Root growth was almost stopped at 90 per cent in Chernozem. This reduction was due to toxicity of high concentration of Mg²⁺ humate.

Asana and Kale (1965) observed that salinity (EC 9.7 mmho/cm) depressed root growth more than shoot growth and

reduced tillering, leaf size and shoot height of the wheat plant.

Lund (1970) studied the effect of Ca^{2+} and its relation to several cations in soyabean root and concluded that low ratio of Ca^{2+} to $\text{Ca}^{2+} + \text{Mg}^{2+}$ (0.1 or less) reduced the root growth. He also reported that Ca^{2+} was necessary at the site of root growth, other ion might affect the morphology of root. In this experiment he showed that Mg^{2+} was the only cation which suppressed the root growth of soyabean probably due to toxicity caused by high levels of Mg^{2+} .

2.2 Effect of Gypsum on Soil Properties and Plant Growth

Baghott et al. (1954) applied gypsum at 2 to 16 t/ac and sulphur at 500 to 3000 lb/ac to alkali soils. The soils were leached three times before cropping and nine times during cropping. In the first year patchy stands were obtained but in the second year excess lucern stands were obtained on all gypsum plots. Gypsum reduced the soil pH and salinity.

Sen and Tewari (1958) demonstrated that the effect of gypsum on the saline constituents of sandy loam soil of average fertility was incubated for the months at 30°C with gypsum at various doses (0, 1 or 5 MT/ac). They reported that gypsum increased the amount of soluble Mg and also salinity (since some CaSO_4 probably dissolved in the water extract) and reduced the concentration of HCO_3^- when gypsum

at the rate of 5 MT/ac was applied, there was a great increase in soluble Na, but not in K.

Yadav and Agrawal (1959) studied dynamics of soil changes in the reclamation of saline-alkali soils of Indo-Gangetic alluvium. They suggested that with plentiful use of irrigation water, even light doses of gypsum which initially resulted in only about 60 per cent reduction in soil exchangeable Na, significantly improved the soil conditions. Gypsum as a source of soluble calcium for cation exchange reactions coupled with adequate provision for leaching. Gypsum was very effective and suitable chemical amendment for the base exchange reactions in replacement of exchangeable sodium.

Boyaskii (1962) demonstrated the effect of gypsum in increasing the effective fertility of solonetz soil of Donbas. Applications of gypsum at the rate of 3.5 MT/ha under presowing cultivation increased the yield of millet by 15 to 19 per cent, maize by 16 per cent and late cabbage by 10 per cent. Gypsum also increased the content of hydrolyzable N and available P in the lower layer during the vegetative period and enhanced the uptake of N, P, K, S and Ca by plants.

Kanwar and Chawla (1963) reported that gypsum application was more effective in saline sodic soils. It decreased pH, electrical conductivity of the soil. Gypsum neutralized

soluble carbonates and bicarbonates and also increased organic Ca and exchangeable Ca in soil.

Afzal and Jabbar (1977) studied the effects of gypsum, copper and zinc on the availability of iron in the saline sodic soil. The interaction between gypsum and iron for iron content of the plants was found to be highly significant. The increased iron content was due to the greater supply of this element at decreased pH and insoluble forms were converted into soluble one with the application of higher rates of calcium sulphate.

2.3 Effect of Ferrous Sulphate on Iron Availability and Plant Growth.

Olsen (1951) studied the utility of FeO and FeSO₄ as soil amendments in greenhouse conditions with grain sorghum as a test crop. The Fe oxides did not influence the growth of sorghum plants. Application equivalent to 1120 kg FeSO₄/ha enhanced the production of chlorophyll in plants, through increased Fe absorption.

Mathers (1970) found that sulphuric acid and ferrous sulphate treatments (250 ppm Fe with 250 ppm H₂SO₄) on calcareous soils increased the yield of hybrid grain sorghum grown in greenhouse. He further reported that in sugarcane chlorosis occurs due to iron deficiency, which could be corrected by foliar sprays and soil treatment with iron compounds.

Mortvedt and Giordano (1971) suggested that both FeSO_4 and $\text{Fe}_2(\text{SO}_4)_3$ were effective for crops at reasonable low rates if they were applied with fluid polyphosphate fertilizer to soil.

Rai et al. (1971) conducted an experiment in pot culture to study the reasons of iron in shallow black soil. Availability of the applied iron was low in this soil. They observed that the beneficial effects of soil application of iron as evidenced by increase in iron concentration of the treated plants than it was in the control plants.

Hodgson et al. (1972) conducted greenhouse experiment with four crops of corn (Zea mays L.) grown over a period of 2 years on a calcareous soil supplied with 56 to 2200 kg/ha Fe as $\text{Fe}_2(\text{SO}_4)_3$. The iron was mixed with the soil and the plants were grown for 6 weeks. The pots were kept barren in the greenhouse during periods between crops. All the levels of Fe additions improved crop growth with optimum response coming at 186 mg/g and above. The iron content of corn plants and readily extractable phase of Fe in the soil, increased following iron supplementation.

Dahiya and Singh (1976) investigated the effects of salinity, alkalinity and iron application on the availability of iron, manganese, phosphorus and sodium in pea crop. They demonstrated that addition of Fe at the rate of 10 ppm increased the dry matter yield significantly. The highest

concentration of Fe was recorded in the soil having a value of exchangeable sodium per cent (ESP) of 40 followed by 20 ESP. The soil having electrical conductivity of 8 mmho/cm and 20 ESP had the lowest concentration of Fe with highest salinity and alkalinity, which was probably due to the dilution effect. The uptake of Fe was highest in the normal soil owing to high dry matter yield.

Anand (1981) studied the effects of application of three levels (0, 25, and 50 ppm) of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ on the growth, yield and availability of Fe in rice. An increasing supply of Fe enhanced the concentration of nutrients in the crop (grain and straw) while the yield was not influenced by the treatments. The application of iron brought about a significant improvement in Mn content of the crop and available Mn status of the soil.

Sakal et al. (1982) studied that field experiment conducted on calcareous soil, the direct and residual effect of iron carriers and compost applied alone and in combination was studied on rice and maize, respectively. The application of 50 kg FeSO_4 /ha alone enhanced the grain yield of rice by 8.7 q/ha with a further increase to 14 q/ha in conjunction with compost at 10 MT/ha. Compost with FeSO_4 improved the percentage distribution of Fe in the grain over an application of FeSO_4 alone.

2.4 Relationship Between Plant Iron and Chlorophyll

Oserkowsky (1933) demonstrated the relationship between chlorophyll and iron both in green and chlorotic pea leaves. The content of iron in the leaf was quite large both in chlorotic and green leaves. Application of more iron to chlorotic leaves invariably led to greening, but only a small amount of iron was metabolically 'active'.

Brown (1956) observed that chlorotic leaves contained less iron and more phosphorus than green leaves, manganese and magnesium concentration were highest where iron concentration was lowest. Available iron supply in soils was a factor related to chlorosis, but could not be used as an absolute index. Occurrence of deficiency in plant species differs in their capacity to utilize different forms of iron, might limit the value of data pertaining to available iron supply as a index to iron deficiency. Chlorosis is dependent upon iron requirement of the plant species and variable factor in growing media which affect this requirement and the available iron supply in soil.

Agrawal and Mehrotra (1963) reported that the chlorosis was ameliorated by the application of Fe-EDTA in the form of a foliar spray. The concentration of Fe-EDTA and the frequency of its application required to ameliorate the chlorosis varied in different plant species. Periodical sprays were necessary to prevent the recovered plants from reverting to the original chlorotic condition. In some

plants the chlorotic leaves had as much or more iron than the normal comparable leaves. The incidence of chlorosis was not found to be related to soil iron extracted in normal ammonium acetate at pH 3 (available iron). The chlorosis in different plant species was probably due to the physiological unavailability of iron, high CaCO_3 content being an important contributory factor.

Marsh et al. (1963) studied the role of iron in chlorophyll metabolism. Concentration of haem on chlorophyll in cow pea leaves was positively correlated with the Fe concentration in the nutrient solution. Protoporphyrin, the precursors of haem, did not accumulate from endogenous substrates in the Fe deficient or normal tissues and its synthesis from amino-levulinic acid was as rapid in Fe deficient as in normal tissues. Thus iron deficiency may limit the formation of amino-levulinic acid, this would be one rate limiting step in chlorophyll synthesis.

O'sullivan (1969) observed that iron chlorosis was more common in alkaline soil. The tissue concentration of iron in grasses enhanced with increasing iron supply up to a value of 2.56 ppm iron in the nutrient solution. Higher content of chlorophyll was evident with increasing iron supply from 0.04 to 2.56 ppm. Above 2.56 ppm iron supply concentration of these two compounds remained relatively steady. There was significant positive relationship between

iron supply and chlorophyll. The most reliable chemical method for identifying deficiency in both grasses appeared to be values of Ca/K and Fe/Mn ratios.

Omar et al. (1971) studied the relationship between total iron in leaves of maize, grown in sandy loam soil with different levels of phosphate and iron with moisture adjusted to 50, 100, or 150 per cent solution. They found that the increase in growth with increased moisture and phosphate, but these factors caused chlorosis and decreased both total and available iron in leaves. They also showed only a poor relationship between total and active iron. The total iron in a leaf does not give a good indication of the adequacy of the element for healthy growth of leaves showing chlorosis may contain as much as or even more iron than healthy leaves.

Dekock et al. (1979) studied active Fe content in tomato plant. They showed that there was no relationship between total iron and active iron fraction, but a significant linear relationship was found between the active iron fraction and the ratio of total phosphorus to total iron. They also presented same investigation for maize plants grown on soil with various levels of moisture, phosphorus and iron.

Ruiz et al. (1980) found that the chlorophyll content was an index of iron chlorosis in nectarine. Leaves of nectarine trees (Cv. LC Grand) were analysed for iron and degree of chlorosis. Chlorophyll content was decreased as symptoms of chlorosis increased.

Chapter Opener Page

M A T E R I A L,
M E T H O D S &
E X P E R I M E N T A L

3. MATERIAL, METHODS AND EXPERIMENTAL

3.1 Material

A greenhouse experiment was conducted at the Mahatma Phule Agricultural University, Rahuri, for assessing the effects of gypsum, ferrous sulphate and quality of irrigation water on chlorosis and growth of sugarcane in saline calcareous soil.

3.1.1 Soil

The soil (0-15 cm) used for the pot culture experiment was collected from the surface horizon of farmers' fields at Baragaon-Nandur village situated on the west of Rahuri town and on the left bank of the 'Mula' river, where extensive chlorosis in sugarcane was observed. The soil was air-dried in the shed and passed through 2 mm sieve. The pertinent physical and chemical properties of the soil are given in Tables 1 and 2.

Table 1. Physical and chemical properties of the soil

Sr. No.	Soil properties	
1	<u>Mechanical composition</u>	
	i) Coarse sand (%)	21.4
	ii) Fine sand (%)	25.9
	iii) Silt (%)	22.2
	iv) Clay (%)	16.8
	v) Textural class	
	vi) Calcium carbonate equivalent (%)	13.7
2	<u>Fertility constituents</u>	
	i) EC (Soil-water 1:2.5 mmho/cm at 25°C)	4.0
	ii) pH-H ₂ O (1:2.5)	8.1
	iii) Organic carbon (%)	1.4
	iv) Total N (ppm)	700
	v) Olsen P (ppm)	16.3
	vi) Available K (ppm)	180
	vii) DTPA extractable micronutrients :	
	Fe (ppm)	3.9
	Mn (ppm)	3.4
	Zn (ppm)	1.8
	Cu (ppm)	0.9

Table 2. Properties of soil, saturation extract and well-water

Property	Soil	Saturation extraction of the soil	Irrigation water
EC (mmho/cm)		4.0	4.9
pH (Soil:Water) (1:2.5)	7.7	8.1	7.3
	Exchangeable bases meq/100 g	meq/L	meq/L
Ca	11.0	10.0	9.9
Mg	14.4	22.0	27.7
Na	12.1	22.2	18.6
K	2.5	0.23	0.04
CO ₃			1.5
HCO ₃		4.0	3.2
Cl		26.6	28.1
SO ₄		24.3	23.6

3.1.2 Irrigation water

The well-water used for irrigating experimental pots was also brought from the farmers' field. Other source of irrigation was the distilled water. The properties of irrigation waters are given in Table 2.

3.1.3 Crop

Sugarcane (Saccharum officinarum, L.) Cv. CO-740 was used as a test crop.

3.2 Methods

3.2.1 Analysis of soil and irrigation water

Analyses of soil and irrigation water were carried out by adopting standard methods given in Table 3.

Table 3. Methods used for analysis of soil and irrigation water

Sr. No.	Soil property	Method used	Reference
1	Mechanical composition	Bouyoucos Hydrometer method	Bouyoucos (1962)
2	Electrical conductivity	Conductometric	Jackson (1958)
3	Soil pH	Potentiometric	Jackson (1958)
4	CaCO ₃ equivalent per cent	Volumetric calcimeter	Black (1965)
5	Organic carbon	Walkley and Black	Allison (1975)
6	Total-N	Macro-Kjeldahl	Piper (1950)
7	Olsen's P	0.05 M NaHCO ₃ (pH 8.5)	Olsen et al. (1954)
8	Available K ⁺	1N NH ₄ OAc (pH 7.0)	Chapman and Pratt (1961)
9	Exchangeable cations	Alcoholic NH ₄ Cl extraction	Tucker (1971)
10	Ca ²⁺ and Mg ²⁺	Versene method	Jackson (1967)
11	Na ⁺ and K ⁺	Flame photometric	Jackson (1967)
12	CO ₃ ²⁻ and HCO ₃	Titrimetric	Richards (1954)
13	Cl ⁻	Titrimetric	Richards (1954)
14	SO ₄ ²⁻	Turbidimetric	Richards (1954)
15	DTPA-extractable Fe, Mn, Cu, Zn.	Atomic absorption spectrophotometric (Varian Tectron-1100)	Lindsay and Norwell (1978)

3.2.2 Plant analysis

The plant samples were analysed by adopting standard methods which are presented in Table 4.

Table 4. Methods used for plant analysis

Sr. No.	Determination	Method used	References
1	Nitrogen	Micro-Kjeldahl	Jackson (1958)
2	Phosphorus	Ascorbic acid blue colour reduction	John (1970)
3	Potassium	Flame Photometry	Chapman and Pratt (1961)
4	Calcium and Magnesium	Atomic absorption spectrophotometry	Parkinson and Allen (1975)
5	Iron and Manganese	Atomic absorption spectrophotometry	Soltanpour et al. (1976)
6	o-Phenanthroline extractable leaf-Fe	Colorimetry	Katyai and Sharma (1980)
7	Total chlorophyll	Acetone Extract	MacKinney (1941)

3.2.3 Statistical method

The statistical analysis of the data obtained from the pot culture experiment was carried out by the standard statistical method (C.R.D.). The analyses of variance and multiple correlation were carried out with micro-computer (Fisher, 1950). The null hypothesis was tested by the test of significance to know whether the observed differences due to the treatments were real or otherwise. The standard error and the critical

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differences at 5 per cent level of probability were calculated.

3.3 Experimental

3.3.1 Pot culture experiment

A pot culture experiment was conducted in plastic pots of 15 litre capacity. To each pot, 20 kg soil (2 mm) was added. A basal dose of nutrients was thoroughly mixed with the soil. The quantities of the various nutrient salts added to each pot are given in Table 5.

Table 5. Basal application of N, P, K, Cu, Zn, Mo and B

Sr. No.	Nutrient	Source	Salts @/pot
1	N	Urea	4.34
2	P	Potassium dihydrogen phosphate	0.75
3	K	Potassium chloride	1.40
4	Cu	Copper sulphate	0.15
5	Zn	Zinc sulphate	0.15
6	Mo	Ammonium molybdate	0.01
7	B	Borax	0.05

3.3.2 Treatment details

The details of treatments are presented in Table 6.

Table 6. The details of treatments

Sr.No.	Symbol	Treatment details
1	C	Control
2	G	Gypsum
3	Fe	Ferrous sulphate
4	G ₁ + Fe (50:1 molar ratio)	Gypsum + Ferrous sulphate (50:1 molar ratio)
5	G ₂ + Fe (100:1 molar ratio)	Gypsum + Ferrous sulphate (100:1 molar ratio)
Irrigation water		
I	Dw	Distilled water
II	Ww	Well water



3.3.3 Quantity of amendments used

The quantity of amendments used are given in Table 7.

Table 7. Quantity of gypsum and ferrous sulphate added per pot

Sr. No.	Treatment	g/pot
1	Gypsum	196.8
2	Ferrous sulphate	3.168
3	Gypsum + Ferrous sulphate (50:1 molar ratio)	196.8 + 3.168
4	Gypsum + Ferrous sulphate (100:1 molar ratio)	393.6 + 3.168

Gypsum and ferrous sulphate were mixed with the upper 2 kg of soil in the pot. Each treatment was replicated thrice. The pots were irrigated with distilled water. Two healthy single budded sets of Cv. CO-740 were planted in each pot to a depth of 5 cm on the 23rd September, 1981. Only one healthy plant was allowed to grow for 160 days.

In order to prevent excess accumulation of soluble salts in the soil, the pots were irrigated with water one litre more than the water holding capacity of the soil. The excess water was allowed to drain through the leaching tube. At the age of 100 days after planting, composite soil sample from each pot was collected and analysed for DTPA extractable iron and manganese. Similar sampling of soil was done on 160 days after planting and soil was analysed for DTPA-Fe and exchangeable bases.

The third leaf from top of sugarcane plant was removed for analysis of leaf-Fe²⁺ and chlorophyll on the 100th day of crop growth. The green leaf was dried in the oven and analysed for N, P, K, Ca, Mg and Fe by adopting suitable methods. Similar analysis was carried out on the 160th day of growth.

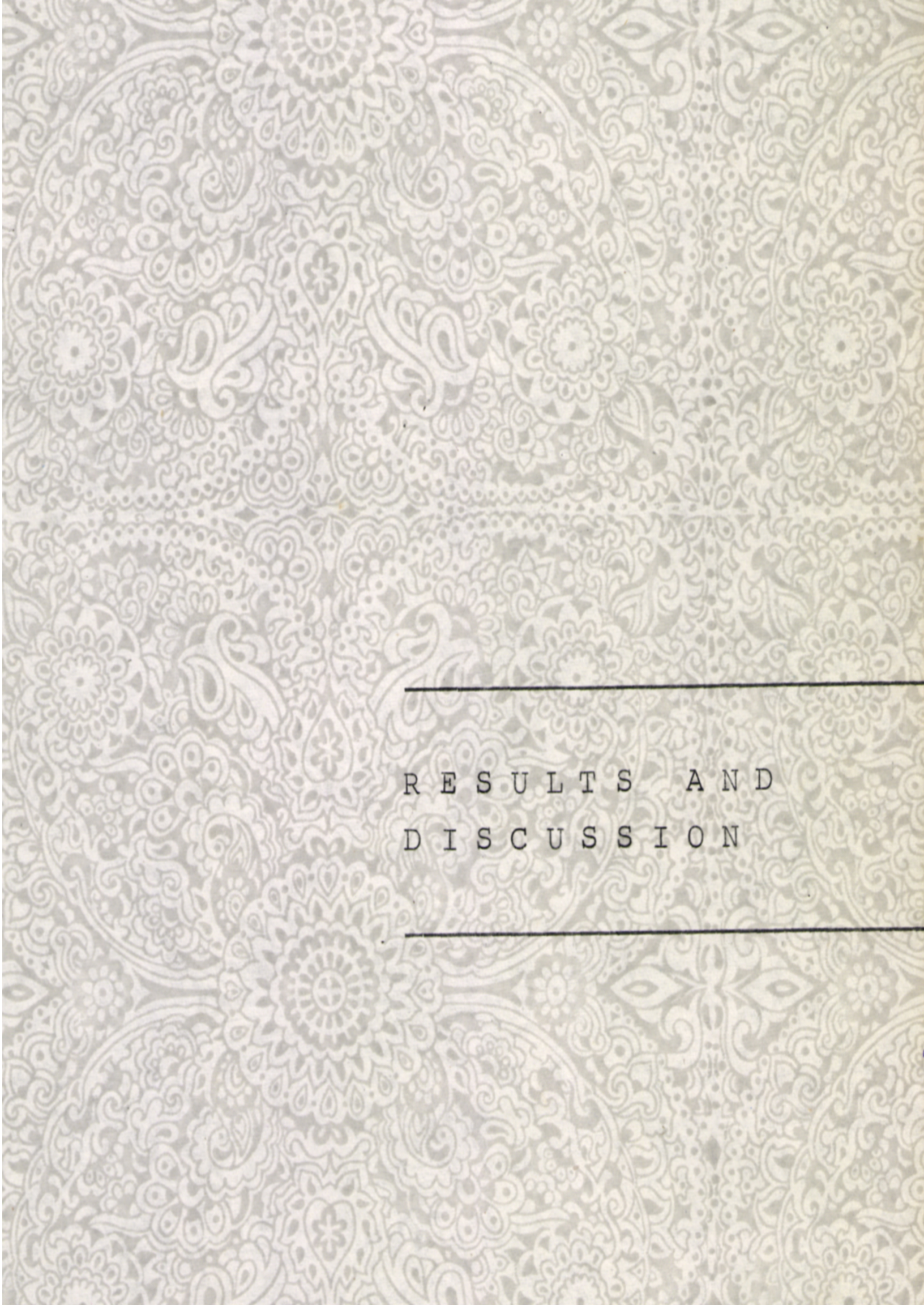
3.3.4 Harvesting

The sugarcane plant tops were sheared at the soil surface on the 5th March, 1982. Tops were dried in the air and then in an oven at 70°C. Dry matter yield of plant tops was recorded.

3.3.5 Root study

Immediately after harvesting the plant tops, roots were taken out from pots and washed with conspicuous water. Fresh, white and tender root samples were collected and washed with distilled water and dried in the oven and analysed for elemental composition viz., Ca, Mg, N, P, Fe and Mn. The total dry matter of roots from each pot was recorded.

Chapter Opener Page



R E S U L T S A N D
D I S C U S S I O N

4. RESULTS AND DISCUSSION

The effects of gypsum, ferrous sulphate and quality of irrigation water on the DTPA-extractable Fe and Mn, pH and exchangeable bases of soil, chlorophyll content, leaf elemental composition, root composition and dry matter of tops and roots of sugarcane are presented and discussed as under :

4.1 Analysis of DTPA-Extractable Fe and Mn, pH and Exchangeable Bases of Soil

4.1.1 DTPA-Fe and Mn

Data pertaining to the analysis of DTPA extract of soil for Fe and Mn are presented in Table 8.

Table 8. Effects of gypsum, ferrous sulphate and quality of irrigation water on periodical DTPA-Fe and Mn content of soil

Treatment	Period from planting (days)			
	100	160	100	160
	DTPA-Fe		DTPA-Mn	
	ppm			
C	4.58	2.46	14.34	7.98
G	4.55	2.09	10.28	6.87
Fe	5.92	4.58	12.15	8.52
G ₁ + Fe	5.99	4.13	11.55	6.50
G ₂ + Fe	5.98	3.78	10.61	7.71
SE ±	0.31	0.30	0.69	0.90
C.D.at 5%	0.90	0.90	NS	NS
Irrigation water				
Dw	5.19	4.07	11.71	5.95
Ww	5.61	2.75	11.86	7.32
SE ±	0.19	0.18	0.44	0.57
C.D.at 5%	NS	0.56	NS	NS

NS = Non-significant.

Judging from the DTPA analysis, the soil did not initially seem to be deficient in Fe^{2+} content as its availability was greatly increased with the application of ferrous sulphate. Inclusion of gypsum with ferrous sulphate had no beneficial effect on the plant available Fe both on 100th and 160th day after its application, but seemed to decrease the DTPA-Fe. The effects were not statistically significant. The DTPA-Fe of soil was not significantly affected due to quality of irrigation on the 100th day after application of ferrous sulphate, but analysis on the 160th day of growth indicated that there was a significant reduction in the DTPA-Fe of soil due to use of well water. This was probably due to salinity and high soluble Ca content of the irrigation water. Similar depressive effect was noticed in the $G_2 + \text{Fe}$ treatment. The DTPA-Mn of soil was not affected due to either of the treatments.

4.1.2 EC and pH of soil

The use of gypsum, ferrous sulphate and their combinations did not consistently affect the pH of the soil compared to that in the control treatment (Table 9). The pots were irrigated with distilled water and well water as per the treatments. The quantity of water used for irrigation was about one litre more than the water holding capacity of soil to prevent accumulation of salts due to irrigation. The excess water drained due to application of distilled water decreased both pH and EC of the soil. The use of well water, however, significantly increased both pH and EC of the soil.

Table 9. Effects of gypsum, ferrous sulphate and quality of irrigation water on pH and EC of soil (1:2.5) on 160 days growth of sugarcane

Treatment	pH	EC mmho/cm
C	7.66	3.73
G	7.64	5.28
Fe	7.70	4.88
G ₁ + Fe	7.70	4.63
G ₂ + Fe	7.66	4.96
SE ±	0.01	0.16
C.D. at 5%	0.03	0.50
Irrigation water		
Dw	7.60	3.73
Ww	7.74	5.66
SE ±	0.006	0.106
C.D. at 5%	0.02	0.31

4.1.3 Exchangeable bases

The soil exchangeable Ca, Mg and Na were not significantly affected due to different treatments, but irrigation with distilled water significantly increased the exchangeable Ca and decreased the exchangeable Mg. The exchangeable Na, however, was not statistically different due to either of the treatments (Table 10). The well water rich in magnesium ions compared to Ca ions increased the exchangeable Mg over exchangeable Ca. Many a times, when concentration of Mg is more than Ca, the Mg behaves like Na. It was probably due to this property that the exchangeable Na remained unchanged as a result of either of the treatments.

Table 10. Effects of gypsum, ferrous sulphate and quality of irrigation water on exchangeable bases of soil on the 160 days growth of sugarcane

Treatment	Exchangeable bases in soil			
	Ca	Mg	Na	K
	meq/100 g of soil			
G	18.78	22.40	8.60	2.02
G	18.55	20.75	7.46	1.17
Fe	17.08	25.03	7.02	1.17
G ₁ + Fe	19.77	23.40	7.46	1.23
G ₂ + Fe	19.65	23.58	7.46	1.76
SE ±	0.70	0.10	0.39	0.14
C.D. at 5 %	NS	NS	NS	0.42
Irrigation water				
DW	21.46	16.11	7.33	1.79
Ww	16.07	25.11	7.87	1.15
SE ±	0.44	0.65	0.24	0.09
C.D. at 5%	1.32	1.90	NS	0.27

NS = Non-significant

4.2 Plant Studies

4.2.1 Total leaf Fe

Data on the total leaf-Fe content are presented in Table 11. The total leaf concentration was not influenced due to any of the five treatments, but the use of saline irrigation water significantly increased the total leaf-Fe of 160 days old plants. The relatively chlorotic and 160 days old plants from the control and gypsum treatments contained 330.35 and 349.98 ppm leaf-Fe, respectively, whereas the green leaves from the treatments, however, were not statistically significant. Data indicate that total

leaf-Fe was not significantly increased due to application of ferrous sulphate.

Table 11. Periodical composition of leaf^{*}-Fe and Mn of sugarcane as affected by gypsum, ferrous sulphate and quality of irrigation water

Treatment	Period from planting (days)			
	100		160	
	Total leaf Fe		Leaf Mn	
	ppm			
C	317.27	330.35	116.91	63.25
G	412.12	349.98	130.53	75.71
Fe	340.08	351.31	118.83	71.88
G ₁ + Fe	350.59	320.54	109.25	83.37
G ₂ + Fe	385.95	366.33	99.67	81.46
SE ±	42.28	43.40	6.23	5.00
C.D. at 5 %	NS	NS	18.33	NS
Irrigation water				
DW	370.51	301.57	117.30	64.02
Ww	351.89	385.83	112.70	86.25
SE ±	26.74	27.50	3.93	3.16
C.D. at 5 %	NS	80.85	NS	9.33

* Third leaf from the top of the plant.

NS = Non-significant.

4.2.2 Total leaf Mn

Like leaf-Fe, the leaf-Mn concentration was significantly increased due to application of well water on the 160th day of plant growth. There was no consistency in the trend of leaf-Mn concentration due to various treatments. The leaf-Mn concentration was, however, decreased with the growth of the plants.

4.2.3 Leaf Ca and Mg

The concentrations of Ca and Mg in the leaves decreased from the level on the 100th day of plant growth to a level on the 160th day of plant growth (Table 12). Neither of the treatments of gypsum and ferrous sulphate nor the quality of irrigation water made any effect on Ca and Mg composition of leaves.

Table 12. Effects of gypsum, ferrous sulphate and quality of irrigation water on the periodical Ca and Mg contents of 3rd leaf of sugarcane.

Treatment	Period from planting (days)			
	100	160	100	160
	Leaf Ca		Leaf Mg	
	/----- % -----/			
C	0.175	0.121	0.711	0.46
G	0.199	0.136	0.933	0.52
Fe	0.225	0.082	0.777	0.50
G ₁ + Fe	0.201	0.122	0.783	0.57
G ₂ + Fe	0.222	0.100	0.807	0.57
SE ±	0.098	0.084	0.052	4.21
C.D. at 5 %	NS	NS	NS	NS
Irrigation water				
Dw	0.20	0.10	0.79	0.48
Ww	0.21	0.13	0.81	0.57
SE ±	0.062	0.053	0.033	2.66
C.D. at 5 %	NS	NS	NS	NS

NS = Non-significant.

4.2.4 Leaf N and P

The plants from the control and gypsum treatments contained maximum concentration of nitrogen (Table 13).

Table 13. Effects of gypsum, ferrous sulphate and quality of irrigation water on the leaf N and P contents of sugarcane leaf

Treatment	Period from planting (days)			
	100	160	100	160
	Leaf-N		Leaf-P	
	%			
C	1.76	2.82	0.079	0.09
G	1.65	2.62	0.077	0.07
Fe	1.46	2.01	0.077	0.09
G ₁ + Fe	1.45	2.19	0.071	0.08
G ₂ + Fe	1.55	2.40	0.065	0.08
SE + C.D. at 5 %	0.089 NS	0.094 0.28	0.006 NS	0.004 NS
Irrigation water				
Dw	1.28	2.26	0.07	0.08
Ww	1.86	2.56	0.08	0.07
SE + C.D. at 5 %	0.057 0.166	0.060 0.175	0.004 NS	0.002 NS

NS = Non-significant.

Application of ferrous sulphate alone or in combination with gypsum sharply decreased the leaf-N on 100 and 160 days of crop growth. The differences were, however, significant only on the 160th day of growth. The limited plant growth might have resulted in decreasing concentration of N in the leaves. Data indicate that chlorotic plants had higher leaf-N compared to green leaves. There was a strong negative relationship between chlorophyll and leaf-N ($r = -0.574$), between DTPA-Fe and leaf-N ($r = -0.731$) and between o-Ph extractable

leaf-Fe and leaf-N ($r = -0.556$) (Table 17). The application of well water resulted in the significant increase in the leaf-N and it was observed on the both periods of plant growth. Neither the treatments of ferrous sulphate nor the quality of irrigation water made any effect on phosphorus concentration of sugarcane leaves.

4.2.5 o-Ph extractable leaf-Fe (o-Ph-Fe)

Data on o-Ph-Fe are presented in Table 14 and in Fig. 1. o-Ph leaf-Fe composition of 100 days old plants on fresh weight basis ranged between 19.4 and 32.2 ppm. The corresponding range for 160 days old plants was 12.0 to 18.2 ppm. The decrease in the o-Ph extractable leaf-Fe concentration at the later age of plants was probably due to the dilution effect owing to increased plant growth. The concentration of o-Ph leaf-Fe in sugarcane was higher under all the treatments containing ferrous sulphate compared to control or gypsum treatment alone. The depressive effect of gypsum on the concentration of plants o-Ph-Fe was not significant. The effect of ferrous sulphate on the o-Ph leaf-Fe concentration was difficult to interpret since large increases in dry matter yield were usually associated with added Fe which could cause a dilution effect on o-Ph-Fe concentration. o-Ph leaf-Fe of 160 days old plants was maximum where ferrous sulphate along with gypsum ($G_1 + Fe$) was applied to the soil. Further addition of gypsum depressed the o-Ph leaf-Fe to 15.3 ppm. The difference, however, was not statistically

significant compared to that of $G_2 + Fe$. The treatments Fe , $G_1 + Fe$ and $G_2 + Fe$ significantly increased the o-Ph leaf-Fe compared to the control treatment.

Table 14. Periodical composition of o-Ph-leaf-Fe* and chlorophyll of sugarcane as affected by gypsum, ferrous sulphate and quality of irrigation water

Treatment	Period from planting (days)			
	100	160	100	160
	o-Ph Leaf-Fe		Chlorophyll	
	ppm		mg/g	
C	19.4	12.0	0.50	0.35
G	19.5	13.6	0.72	0.66
Fe	24.5	16.9	1.01	1.03
$G_1 + Fe$	27.0	18.2	1.03	1.17
$G_2 + Fe$	32.2	15.3	0.96	0.87
SE \pm	3.07	1.16	0.14	0.13
C.D. at 5 %	0.80	3.42	NS	0.39
Irrigation water				
Dw	24.98	15.36	0.89	0.86
Ww	24.15	14.90	0.81	0.78
SE \pm	1.94	0.73	0.09	0.09
C.D. at 5 %	NS	NS	NS	NS

* On fresh weight basis.

NS = Non-significant.

Use of saline water did not show any significant effect on o-Ph leaf-Fe content in sugarcane. A strong positive correlation ($r = 0.537$) between o-Ph leaf-Fe and DTPA-Fe of soil on the 160th days growth indicated that available Fe in the plant probably controlled the o-Ph leaf-Fe of sugarcane.

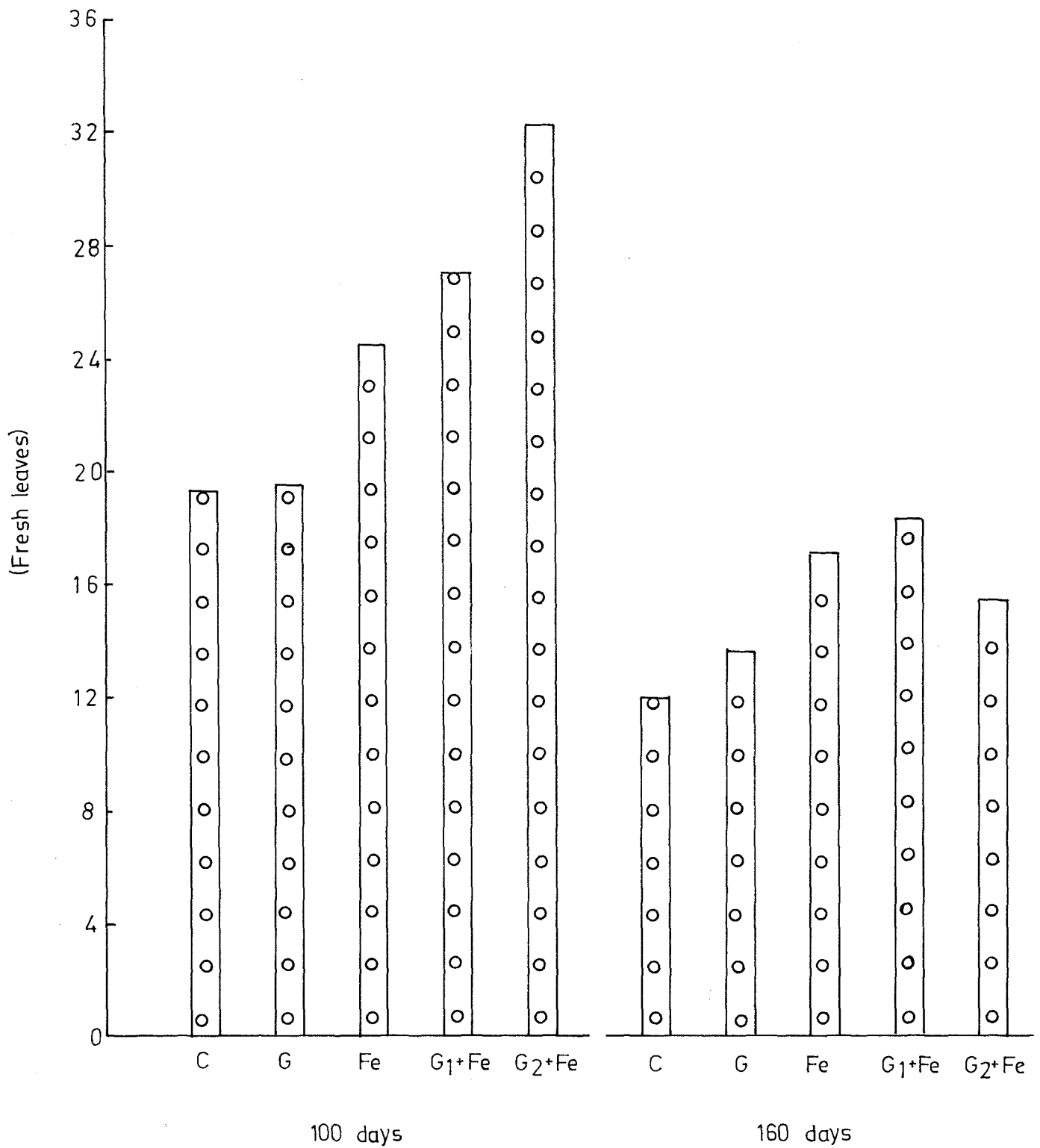


Fig.1. Periodical analysis of leaf-Fe²⁺ as affected by application of gypsum and ferrous sulphate.

4.2.6 Chlorophyll content

The chlorophyll content of sugarcane leaves was significantly affected by ferrous sulphate treatments with much of the effect being due to increase in o-Ph leaf-Fe (Table 14 and Fig. 2). Chlorotic symptoms, though less intense, were seen in the control and gypsum treatments even after 100 and 160 days of growth. During the growth period of the plant, chlorophyll content was maximum in the $G_1 + Fe$ treatment on the 160th day of growth. The chlorophyll content in leaves was enhanced with increasing o-Ph leaf-Fe up to 18.2 ppm. A significantly positive relationship ($r = 0.545$) between chlorophyll and o-Ph leaf-Fe observed on the 160th day of growth confirms the findings of Dekock (1979) and Sanas (1983) that chlorophyll formation probably depended on orthophenanthroline (pH 5.1, 1.5 %) extractable o-ph Fe of fresh sugarcane leaves. The increasing addition of gypsum to ferrous sulphate depressed the chlorophyll content of sugarcane leaves at both the periods of analysis. The difference, however, was not statistically significant. The quality of irrigation water made no difference on the chlorophyll content of leaves.

4.2.7 Root composition

Data in respect of elemental composition of sugarcane are given in Table 15. The Fe, Mn and P content of roots was significantly increased due to the application of ferrous sulphate compared to that in the control and gypsum treatments.

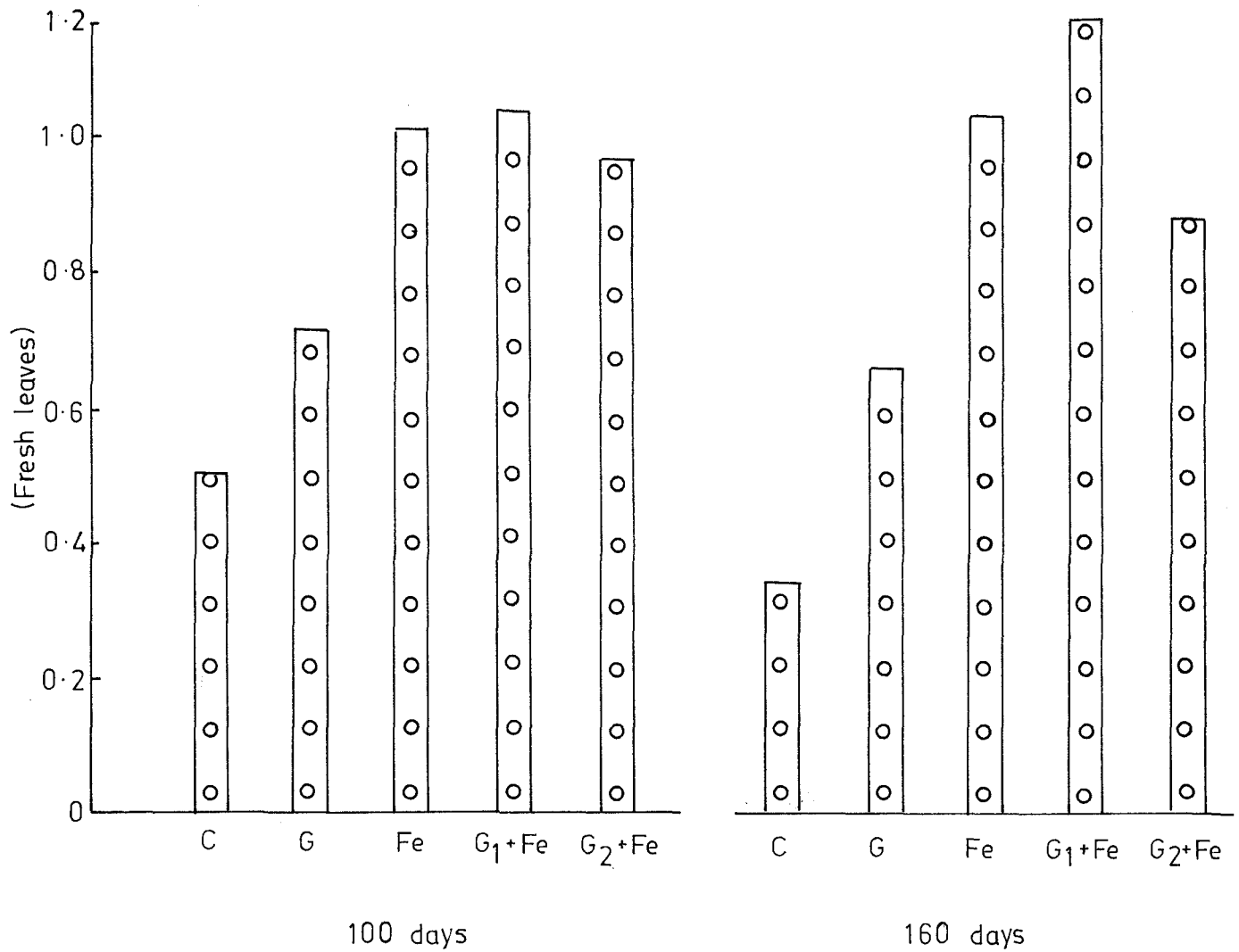


Fig.2. Periodical analysis of total chlorophyll as affected by application of gypsum and ferrous sulphate.

Table 15. Effects of gypsum, ferrous sulphate and quality of irrigation water on the composition of sugarcane roots.

Treatment	Fe	Mn	Ca	Mg	N	P
	/----- % -----/					
C	0.11	0.0060	0.36	0.66	1.92	0.050
G	0.10	0.0062	0.53	0.60	1.70	0.056
Fe	0.17	0.0079	0.45	0.73	1.65	0.072
G ₁ + Fe	0.13	0.0042	0.43	0.74	1.83	0.068
G ₂ + Fe	0.13	0.0051	0.43	0.55	1.77	0.062
SE ±	0.01	0.0008	0.05	0.03	0.05	0.002
C.D. at 5%	0.03	0.0024	NS	0.09	0.15	0.010
Irrigation water						
Dw	0.17	0.01	0.53	0.63	1.79	0.065
Ww	0.08	0.01	0.44	0.73	1.75	0.060
SE ±	0.006	0.005	0.030	0.019	0.032	0.0017
C.D. at 5%	0.02	NS	0.088	0.06	NS	0.01

NS = Non-significant.

The root Ca and Mg composition was in accordance with the higher Mg concentration than with Ca in the well water. The G and G₂ + Fe treatments significantly decreased the Mg concentration of roots than did the Fe and G₁ + Fe treatments. The root nitrogen was minimum in the ferrous sulphate treatment and maximum in the control treatment. The roots of chlorotic plants contained higher root-N concentration. Similar observations were recorded by Sanas (1983). The study indicated that the application of ferrous sulphate significantly decreased the nitrogen accumulation when compared with that in the control treatment. The inclusion of gypsum with ferrous sulphate also increased the root-N.

The use of saline water decreased root concentration of both Fe and P. The Ca content of roots was significantly decreased while that of Mg increased due to the application of well water.

4.2.8 Dry matter yield of sugarcane tops and roots

Application of ferrous sulphate alone or in combination with gypsum resulted in significant increases in the dry matter yields of both sugarcane tops and roots as compared to that in the control and gypsum treatments (Table 16 and Fig. 3 & 4). However, yield decreased with the increasing application of gypsum with ferrous sulphate ($G_1 + Fe$ and $G_2 + Fe$) as compared with that due to application of ferrous sulphate alone (Table 16)

Table 16. Effects of gypsum, ferrous sulphate and quality of irrigation water on dry matter yield of sugarcane tops and roots.

Treatment	Dry matter yield	
	Tops	Roots
	g/pot	
C	29.80	4.86
G	18.71	5.66
Fe	53.45	17.33
$G_1 + Fe$	48.25	10.50
$G_2 + Fe$	39.80	8.40
SE \pm	5.02	1.41
C.D. at 5 %	14.81	4.18
Irrigation water		
Dw	44.14	9.35
Ww	38.00	7.39
SE \pm	3.17	0.89
C.D. at 5 %	NS	NS

NS = Non-significant.

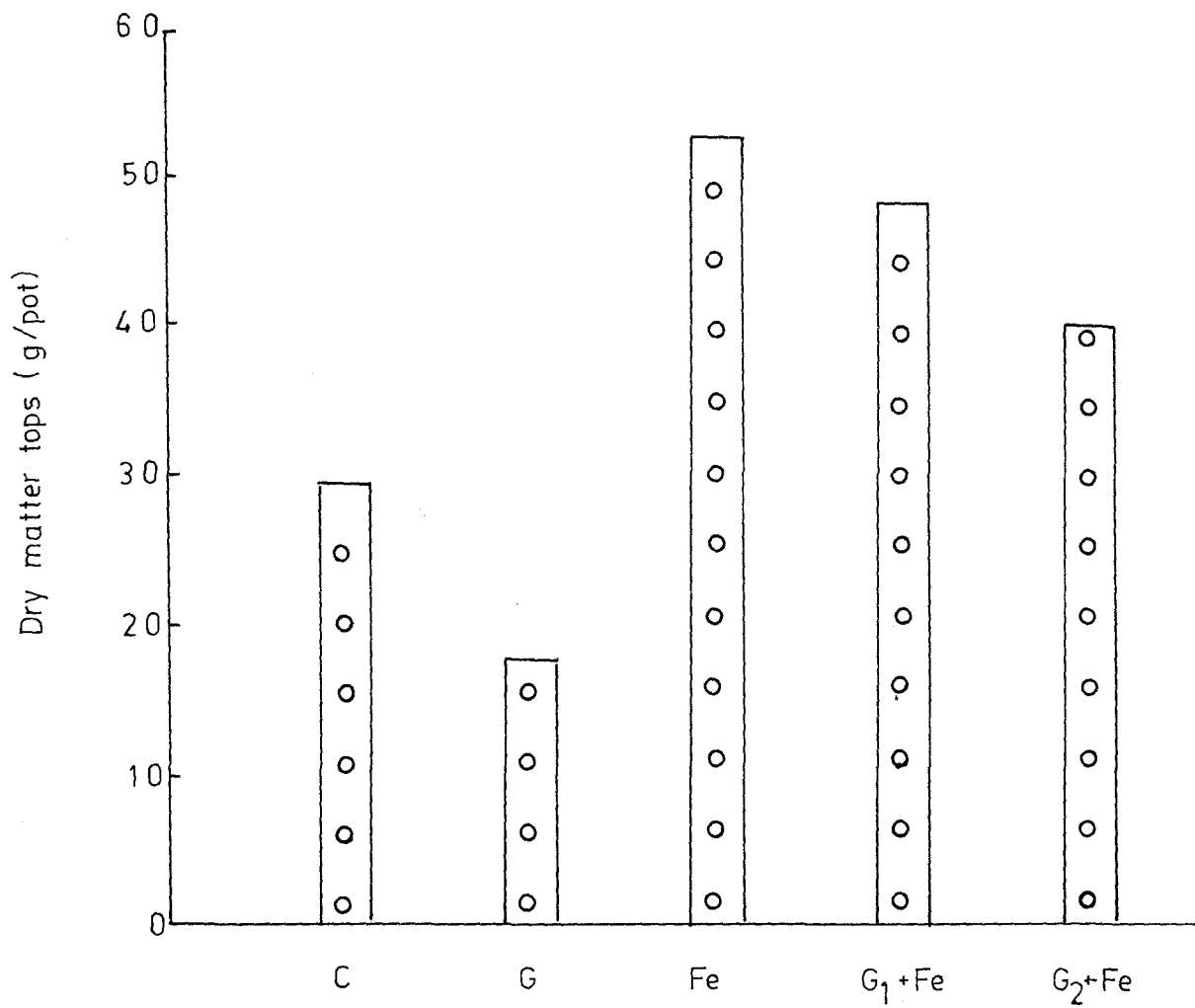


Fig.3. Dry matter yield of sugarcane tops as affected by application of gypsum and ferrous sulphate.

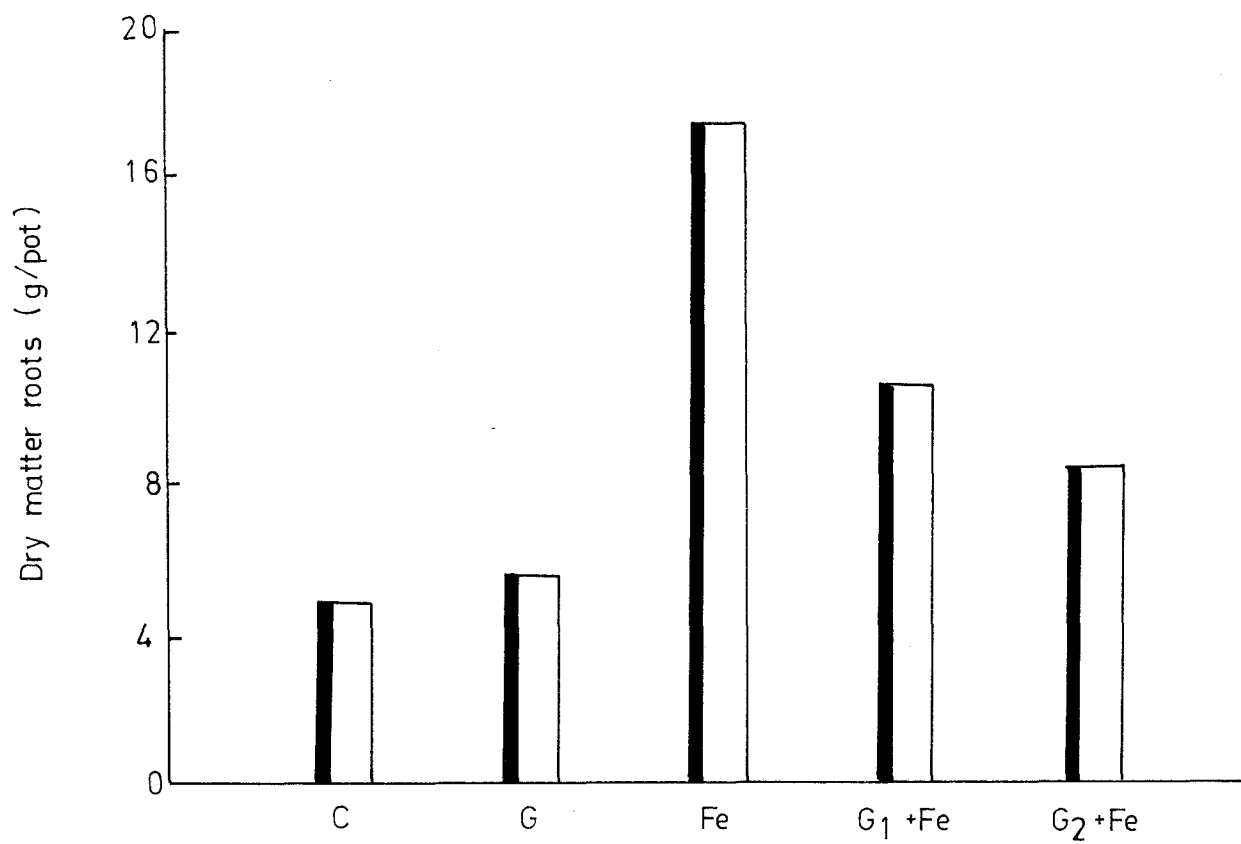


Fig.4. Dry matter yield of sugarcane roots as affected by application of gypsum and ferrous sulphate.

Yield increases were large in response to applied ferrous sulphate, but when gypsum was included in ferrous sulphate, sugarcane dry matter decreased from 53.45 to 39.8 g/pot. These decreases were correlated with a marked decrease in DTPA extractable Fe of soil ($r = 0.48$) and chlorophyll content of leaves ($r = 0.50$) (Table 17).

Table 17. Correlation coefficients (r) between soil and plant parameters at two periods of sugarcane growth

Sr.No.	Correlation	Period from planting (days)	
		100	160
1	DTPA-Fe and chlorophyll	0.336	0.451**
2	DTPA-Fe and o-ph leaf-Fe	0.554**	0.537**
3	DTPA-Fe and leaf-N	-	-0.731**
4	DTPA-Fe and tops (dry matter)	-	0.481**
5	DTPA-Fe and roots (dry matter)	-	0.569**
6	Chlorophyll and o-Ph leaf-Fe	0.224	0.545**
7	Chlorophyll and leaf-N	-	-0.574**
8	Chlorophyll and root-Fe	-	0.373*
9	Chlorophyll and tops (dry matter)	-	0.504**
10	Chlorophyll and roots (dry matter)	-	0.555**
11	o-Ph leaf-Fe and leaf-N	-	-0.556**
12	o-Ph leaf-Fe and root-Fe	-	0.249
13	o-Ph leaf-Fe and tops (dry matter)	-	0.455**
14	o-Ph leaf-Fe and roots (dry matter)	-	0.828
15	Tops (dry matter) and roots (dry matter)	-	0.819**
16	Tops (dry matter) and root-P	-	0.440*
17	Roots (dry matter) and root-P	-	0.501**

* Significant (0.05)

** Significant (0.01)

- 1. C
- 2. G
- 3. Fe
- 4. G₁+Fe
- 5. G₂+Fe



Distilled water



- 1. C
- 2. G
- 3. Fe
- 4. G₁+Fe
- 5. G₂+Fe

Well water

Plate - 1. Effect of gypsum, ferrous sulphate and quality of irrigation water on root growth of sugarcane .

Chapter Opener Page

S U M M A R Y A N D
C O N C L U S I O N

5. SUMMARY AND CONCLUSION

A pot culture experiment was conducted to study the effects of gypsum, ferrous sulphate and quality of irrigation on the chlorosis and growth of sugarcane. The soil studies included EC, pH, exchangeable bases and DTPA extractable Fe. The plant studies included elemental composition of the third leaf from the top of sugarcane, the o-Ph leaf-Fe and chlorophyll.

5.1 Soil Studies

The DTPA extractable Fe of soil was significantly increased due to the application of ferrous sulphate. Inclusion of gypsum with ferrous sulphate had no beneficial effect on DTPA-Fe of soil both on the 100th and 160th days after its application, but seemed to decrease the DTPA-Fe. The DTPA-Fe of soil was not significantly affected due to quality of irrigation water on the 100th day after application of ferrous sulphate, but the analysis on the 160th day of growth indicated that there was a significant reduction in the DTPA-Fe of soil. The DTPA-Mn of soil was not affected due to either of the treatments.

The application of distilled water decreased both the pH and EC of soil, whereas use of well water significantly increased both pH and EC of soil. The soil exchangeable Ca, Mg and Na were not significantly affected due to gypsum and ferrous sulphate. The use of distilled

water significantly increased the exchangeable Ca and decreased the exchangeable Mg. The exchangeable Na, however, was not statistically changed due to either of the treatments.

5.2 Plant Studies

The total leaf-Fe concentration was not influenced due to any of the five treatments. However, the use of saline irrigation water significantly increased the total leaf-Fe of 160 days old plants. The concentration of Ca and Mg in the leaves decreased from the level on 100th day of plant growth to a level on 160th day of plant growth. Neither the treatments of gypsum and ferrous sulphate nor the quality of irrigation water made any effect on Ca and Mg composition of leaves. Application of ferrous sulphate alone or in combination with gypsum sharply decreased the leaf-N at both the periods of growth.

The data indicated that chlorotic plants had higher leaf-N as compared to that of the green leaves. There was a strong negative relationship ($r = -0.574$) between chlorophyll and leaf-N. Application of well water resulted in the significant increase in leaf-N and was observed on the both periods of plant growth. Neither the treatments of ferrous sulphate nor the quality of irrigation water made any effect on phosphorus concentration of sugarcane leaves.

The concentration of o-Ph leaf-Fe in sugarcane was

higher under all the treatments containing ferrous sulphate compared to control or gypsum treatment. Use of saline water did not show any significant effect on o-Ph leaf-Fe content in sugarcane. A strong positive correlation ($r = 0.537$) between o-Ph leaf-Fe and DTPA-Fe of soil on the 160th day of growth indicated that DTPA-Fe of soil probably controlled the o-Ph leaf-Fe of sugarcane.

Chlorophyll content was significantly affected due to ferrous sulphate treatments with much of the effect being due to increase in o-Ph leaf-Fe. A significantly positive relationship between chlorophyll and o-Ph leaf-Fe ($r = 0.545$) was observed on the 160th day of growth of sugarcane. The quality of irrigation water made no difference in the chlorophyll content of leaves.

The Fe, Mn and P content of roots was significantly increased due to application of ferrous sulphate as compared to that in the control and gypsum treatments. The root Ca and Mg composition was in accordance with the higher Mg concentration than with Ca in the well water. The Ca content of roots was significantly decreased while that of Mg increased due to application of well water. The roots of chlorotic plants contained higher root-N concentration. The use of saline water decreased root concentration of both Fe and P.

Application of ferrous sulphate alone or in combination

with gypsum resulted in the significant increases in dry matter yields of both sugarcane tops and roots compared to that in the control and gypsum treatments. Root growth of sugarcane decreased when Ca concentration was increased. The quality of irrigation water did not make any difference on the growth of sugarcane indicating that iron availability was probably the main reason for variation in the dry matter production of both tops and roots.

The data indicated that it is possible to improve the chlorotic condition of sugarcane plants by mixing FeSO_4 with saline soil to improve the growth of sugarcane plants, most probably by removing iron stress as was evidenced by the higher DTPA extractable Fe of soil, leaf chlorophyll *o*-Ph-leaf-Fe and the higher dry matter production.

Chapter Opener Page

L I T E R A T U R E
C I T E D

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Chapter Opener Page

7. VITA

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A candidate for the degree of Master of Science in
Agriculture.

Title of the thesis	Effects of gypsum, ferrous sulphate and quality of irrigation water on chlorosis and growth of sugarcane (<u>Saccharum officinarum</u>)
Major field	Soil Science
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