ON-FARM STUDIES ON THE DIAGNOSIS AND MANAGEMENT OF IRON CHLOROSIS IN GROUNDNUT IN KURNOOL DISTRICT OF ANDHRA PRADESH

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

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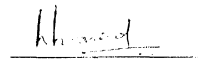
DECLARATION

I declare that this thesis entitled "**ON-FARM STUDIES ON THE DIAGNOSIS AND MANAGEMENT OF IRON CHLOROSIS IN GROUNDNUT IN KURNOOL DISTRICT OF ANDHRA PRADESH**" is a bonafide record of work done by me during the period of research at ICRISAT, Patancheru. This thesis has not formed in whole or in part, the basis for the award of any degree or diploma.



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ABSTRACT

Iron chlorosis is a major nutritional constraint to groundnut (*Arachis hypogaea L.*) production in the Rayalseema region of Andhra Pradesh. This study integrates farmers' perceptions and management practices for Fe chlorosis in groundnut with a follow-up on-farm trial which evaluated 3 genotypes (TMV 2, ICGS 11, ICGV 86031), 3 fertilizer practices (no fertilizer, farmers practice, recommended practice), and 2 foliar Fe sprays (± Fe sprays) for their effect on Fe chlorosis in groundnut.

Survey results revealed that Fe chlorosis as the major constraint to groundnut production causing yield losses between 20 and 40%. Calcareous and alkaline soil characteristics, use of Fe inefficient genotype, mismanagement of irrigation water, and application high N doses were the main causes for Fe chlorosis. Farmers often mistook Fe deficiency symptoms for N deficiency and responded with high doses of nitrogenous fertilizers.

Results from the on-farm trial showed that TMV 2 and ICGS 11 are susceptible to Fe chlorosis resulting in poor growth and yields. ICGV 86031 appeared highly tolerant to Fe chlorosis and yielded better than TMV 2. Extractable Fe and chlorophyll content in young leaves were better indices for Fe estimating status of the groundnut. Fertilizer effects were nonsignificant. Foliar Fe sprays were effective for correcting Fe chlorosis and the improved genotype increased pod yields by about 20%. This study indicated that Fe chlorosis results in about 17% loss of pod yield.

INTRODUCTION

CHAPTER I

INTRODUCTION

In the Indian oil seed scenario groundnut is the largest component and occupies 45 % of total oilseeds area while contributing 55 % of total production. Although India ranks first globally in terms of groundnut area and total production, it ranks 10th in productivity per unit area. Groundnut is predominantly grown in three different seasons i.e., rainy season (Kharif), postrainy season (Rabi), and summer season. In rainy season, it is grown under rainfed conditions, and in postrainy and summer season it is grown under irrigated conditions.

Andhra Pradesh is one of the major groundnut growing states in India with an estimated area of 11.8 lakh ha with an average productivity of 800 kg ha^{-1}. Yields are low and stagnated over recent years. In order to increase oilseed production to its expected level, efforts need to be made to increase unit area productivity since further expansion of area is limited. The first and most important step is to identify farmer-level constraints to groundnut production.

Several constraints such as poor soil fertility, moisture stress, improper fertilizer management, untimely plant protection, poor weed control measures, and nutritional disorders have been attributed to low productivity. One important cause for low yields is the occurrence of micronutrient disorders. Over the years much emphasis has been laid on correcting nutrient deficiencies of phosphorus, sulphur, and zinc. Other micronutrient deficiencies are prevalent in groundnut, but have received little research attention.

In addition to zinc, iron chlorosis (Fe chlorosis) is emerging as a major constraint to production in several states of India including Andhra Pradesh, Gujarat, Haryana, Maharashtra, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh. Several other crops in these areas have been reported suffering from Fe chlorosis (Kannan, 1988).

In Andhra Pradesh, the Rayalseema region is a major groundnut growing area where this crop is reported as suffering from Fe chlorosis. Though soils in this region are rich in Fe content, most is in a form which plants cannot utilize (Bhaskar, 1990). The amount of available Fe not only depends upon soil factors but also on plant species, genotypes within a species, and management practices. Most farmers in this region grow the local variety (TMV 2) which is highly susceptible to Fe chlorosis, which results in poor growth and consequently significant yield losses can occur depending on its severity (Potdar and Anders, 1992; Reddy *et al.*, 1993). Farmers in these areas often mistake Fe chlorosis symptoms for nitrogen deficiency and respond with high doses of nitrogenous fertilizers. High fertilizer doses may aggravate Fe chlorosis depending upon the form of nitrogen applied.

Recent reports have indicated a gradual increase in the area affected by Fe chlorosis in several parts of India (Kannan, 1988). These reports highlighted the importance of this problem, but did not provide any quantitative data on the extent of Fe chlorosis and associated yield losses. These studies were conducted mostly under on-station field or greenhouse conditions, and resulted in recommendations being made for correction of Fe chlorosis. However, no attempt has been made to assess losses from

this problem under on-farm conditions and tested the economic feasibility of recommended practices for correcting Fe chlorosis.

To adequately address these issues studies are required to identify farmer-level constraints to crop production. Similarly, developing a new technology should be based on farmers' perceptions about the problem and management practices easily adopted by them. An effective strategy for Fe chlorosis must involve combined use of Fe efficient cultivars, good management practices, and a reasonably effective Fe fertilizer (Mortvedt, 1986). Information on such integrated Fe management strategies for groundnut is not available in India.

The present study was therefore undertaken to integrate farmers' perceptions and management practices for Fe chlorosis in groundnut with a follow-up on-farm study to evaluate key management practices viz., genotypes, fertilizer practices, and foliar Fe sprays for the diagnosis and correction of Fe chlorosis. Major objectives of this present study are:

1. To quantify farmers' perceptions and management practices for iron chlorosis.
2. Identify main causes for iron chlorosis.
3. Evaluate key management practices for correction of iron chlorosis.
4. Quantify yield losses due to iron chlorosis.
5. Suggest possible management strategies to alleviate this problem.

CHAPTER II

REVIEW OF LITERATURE

2.1 Occurrence of iron chlorosis

Iron (Fe) chlorosis of plants is one of the major nutritional disorders prevalent on calcareous, and sandy soils in arid and semi-arid regions of world (Mortvedt, 1986). It is becoming a major nutritional concern over the globe in different crops causing economic yield losses (Kannan, 1988; Mortvedt, 1991). Peanut (*Arachis hypogaea* L.) is susceptible to Fe deficiency in several countries including Indonesia (Field and Kameli, 1987), Israel (Hartzook, 1975), Taiwan (Lee *et al.*, 1983), Thailand (Ratanarat *et al.*, 1987), U.S.A. (Young, 1967), Cyperus (Paspastylianou, 1989), and India (Potdar and Anders, 1992). It has been estimated that about one third of world's soils are calcareous with high potential for iron chlorosis (Brown, 1961).

In India, Fe chlorosis is one of the factors limiting yields in a large number of crops including groundnut (Kannan, 1988; Morris *et al.*, 1990; Potdar and Anders, 1992,1993). It has been reported that about 19% of the soils in Tamil Nadu, 16% in Punjab, 15% in Uttar Pradesh, 11% in Gujarat are considered to be deficient in Fe (Sekhon, 1982), thus crop grown under these soils often suffer due to Fe deficiency.

In many parts of semi-arid and coastal regions of Andhra Pradesh, Fe chlorosis is a serious problem affecting rice nurseries, groundnut, maize, cotton, sorghum, citrus and grapes (Shiv Raj, 1987).

REVIEW OF LITERATURE

In Andhra Pradesh groundnut is mainly grown in Rayalaseema region comprising of Anantapur, Kurnool, Cuddapah, and Chittor districts. Groundnut crop in these districts often suffers from Fe chlorosis and its severity is increasing in the recent years (Bhaskar, 1990; Ashalatha, 1991). In Kurnool district alone it has been observed that about 10% of the total groundnut area is subjected to Fe chlorosis. The problem is more severe in *rabi* groundnut and it has been estimated that about 10,000 ha area is severely affected by Fe chlorosis (Dooraiswamy[1], 1992).

2.2 Physiology of Fe chlorosis

2.2.1 Functions of Fe in plant nutrition

Among micronutrients, Fe was the first nutrient element discovered as essential for plant life. Gris (1844) corrected chlorosis in grapevine by foliar application of ferrous sulphate thus establishing the essentiality of Fe for growth and development of higher plants. Iron has been considered to be associated with chlorophyll formation because any of its deficiency in the plant system results in foliar chlorosis. In a healthy plant most of the Fe absorbed is concentrated in chloroplast (Price, 1968), and a very few of it is accumulated in the cytoplasm and other cell organelles which contain additional heme and iron-sulphur proteins (Pushnik *et al.*, 1984).

In chloroplast Fe is found in several distinct forms such as cytochrome, peroxidase, catalase, and ferredoxin. The activity of these compounds is reduced under Fe deficiency. In addition to these it has been further observed that the levels of neoxanthin and

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violaxanthin pigments in sunflower and groundnut leaves were reduced due to Fe deficiency (Monge *et al.*,1987). Plants deficient in Fe has low levels of chlorophyll, carotene (Singh *et al.*, 1990) and xanthophyll content (Terry and Low, 1982), and also results in impaired chlorophyll membrane system (Spiller and Terry, 1980).

In the plant system Fe plays an important role in a series of metabolic activities involving respiratory enzymes and various photosynthetic reactions. Iron also plays an important role in legumes for nodulation and nitrogen fixation. It is not only essential element required by legume host plants but also the rhizobium, failure of the infecting rhizobia to obtain adequate amounts of Fe from the plant results in arrested nodule development and failure of the host plant to fix nitrogen in adequate amounts (Dilworth and Glenn, 1984; Hemantharajan and Garg, 1986; O' Hara *et al.*,1988). In addition Fe application also improved protein content in groundnut kernels (Nagaraj, 1987).

2.2.2 Absorption and translocation of Fe by plants

Iron is one of the abundant elements in the earth crust but its uptake and utilization depends on the mechanism of ion absorption which reside at the cell membrane. Fe is considered to be reasonably mobile for a shorter period of time after absorption in both monocots and dicots (Kannan and Pandey, 1982), but in the later its mobility is very much decreased. Its transport from the nutrient solution to shoot is dependent upon the metabolic activity of the root cells. A normal groundnut plant can take up Fe from colloidal particles of roots surface (Branston and Jacobson, 1962). In general, Fe is translocated

through conducting tissues and reaches the actively growing young tissues where it is utilized in various metabolic activities.

Most of the plants have a preferential uptake of Fe in ferrous (Fe^{2+}) form than ferric (Fe^{3+}) form. Several chemical compounds in the rhizosphere are known to be involved in absorption and translocation of Fe in different plant species (Blenfait, 1983).

In graminaceae plants the mechanism of absorption and transport of Fe involves the excretion of mugenic acid from the roots which aid Fe^{3+} solubilization and reduction of Fe^{3+} to Fe^{2+} (Mino *et al.*, 1983) which plants can easily take up. The availability of inorganic Fe to plant roots appears to be dependent on the ability of the roots to lower the pH and to reduce Fe^{3+} to Fe^{2+} in the rhizosphere (Brown, 1978). Iron is not mobile in the plant system, therefore the typical Fe chlorotic symptoms are observed in the younger plant parts where as the older plant parts remain green.

2.2.3 Strategies for Fe uptake

Plant species and genotypes differ in their mechanism to absorb Fe from the soil under deficient conditions. Two types of Fe absorption mechanisms i.e., Strategy I and Strategy II, are known depending on the type of response exhibited by them (Brown and Jolley, 1989; Romheld and Marschner, 1986; Marschner *et al.*, 1986).

Strategy I (mostly exhibited by dicotyledons) is characterized by the following mechanisms:

a. Enhanced reduction of Fe^{3+} to the soluble Fe^{2+} form at the plasmalemma (Blenfait, 1983).

b. Increased H^+ ion afflux at the root via an ATPase pump to lower the pH of the rhizosphere and favor formation of Fe^{2+} (Brown, 1978; Landsberg, 1986).

c. Release of plant produced reductant capable of reducing Fe^{3+} to Fe^{2+} (Brown, 1978).

d. Increased production of organic acids, particularly citrate (Tiffin, 1966).

Whereas, Strategy II (mostly exhibited by the monocotyledons) is characterized by the production and release of Fe solubilizing compounds termed as "photosiderophores" (Romheld and Marschner, 1986; Takagi, 1976), which are capable of forming complexes with sparingly soluble Fe^{3+} and rendering its availability for uptake by plants.

2.3 Diagnosis of Fe deficiency

Diagnosis of nutrient deficiency is usually done by three methods i.e., visual deficiency symptoms, soil analysis and plant analysis. Integration of all the three methods is essential for accurate diagnosis of Fe deficiency.

2.3.1 Visual deficiency symptoms

Iron deficiency results in chlorosis of the younger leaf tissue. In most of the species interveinal chlorosis with fine reticulate pattern is observed in newly formed leaves. The dark green veins are clearly visible against yellow background. The youngest leaves are completely white and devoid of chlorophyll (Mengel and Kirkby, 1979).

In groundnut, leaflets show crinkled margins at an age of three weeks giving the plant a ragged appearance followed by an interveinal chlorosis. It develops long internodes and stems which are of smaller diameter (Reid and York, 1958). Similarly , Narayanan and Reddy (1983) reported that in groundnut plants, initially the interveinal tissue turned chlorotic and the veins remained green but at the later stages the veins also lost their green color and the whole leaf including petiole became yellow.

2.3.2 Soil analysis

One of the most effective means of determining whether a particular nutrient is limiting or not is the soil test. There are few reports in the literature on the evaluation of Fe soil tests. Several methods have been devised to extract Fe from soil, yet no method had received wide application and accepted as standard (Olsen, 1965). However, the DTPA method developed by Lindsay and Norvell (1978) is presently in use for estimation of Fe in soils, the critical range is reported to be 2.5 to 4.5 ppm. Even this is not always dependable as the availability of Fe depends on many other factors besides extractable amount in the soil. Some of these are even inherent in the plant.

In India critical values for DTPA extractable Fe range from 4.5 ppm to 6.4 ppm (Takkar and Mehta, 1986). Currently DTPA extractable Fe in the soils is considered to be a satisfactory guide to the availability of Fe for plant growth (Chen and Barak, 1982).

2.3.3 Plant analysis

The prediction of micronutrient deficiencies based on tissue analysis has been

reasonably successful for all the micronutrients except Fe (Cox and Kamprath, 1972). Current analytical techniques for diagnosing Fe deficiency in plants are generally considered unsatisfactory, because total Fe concentration in plants do not correlate well with plant growth response to Fe (Wallace *et al.*, 1976a; Katyal and Sharma, 1980). Alternative procedures recommended include determination of Fe solution in 1.0 M HCl (Jacobson, 1945) and Fe extracted with 1.5% o-phenanthroline (Katyal and Sharma, 1980).

O-phenanthroline extractable Fe (Fe^{2+}) in the youngest fully opened leaves of peanut, soybean and mungbean were inversely related to the degree of Fe chlorosis, thus it can be used as an index to diagnose Fe chlorosis in plants (Parkpian *et al.*, 1986).

The sufficiency range of Fe content in groundnut varied from 50 to 300 ppm depending on the plant part sampled and age of sampling (Small and Ohlrogge, 1973). Fe chlorosis always occurred only when the youngest leaves (bud or first leaf) contained less than 6 μg extractable Fe g^{-1} fresh wt. (Rao *et al.*, 1987).

The other quantitative measure of diagnosing Fe deficiency is ratios of Fe to other elements suspected to inhibit the absorption of Fe or causing its internal inactivation, when present in excessive quantities. Dekock *et al.* (1960) found that P/Fe ratio was more indicative of Fe chlorosis than Fe concentration in mustard. Similarly ratio of K/Ca and of tricarboxylic organic acids were reported to be higher in chlorotic leaves. The other ratios such as P/Fe and Fe/N were also used to separate chlorotic plants from healthy plants, but not reflected the cause of Fe deficiency (Atkas and Vanegmond, 1979).

Generally Fe content in the leaf is positively correlated with chlorophyll content. Thereby change in the chlorophyll content may be a sensitive indicator of Fe nutrition in crops (Simmons *et al.*, 1963). Chlorophyll estimation in the leaf tissue is an alternative and rapid method for Fe content. In field conditions 7 mg g^{-1} chlorophyll in groundnut leaves gave normal yields (Singh *et al.*, 1987).

2.4 Causes of Fe chlorosis in plants

Several factors related to soil, climate, and plant can contribute to Fe chlorosis has been summarized in reviews of Brown (1961) and Chen and Barak (1982).

2.4.1 Soil factors

Availability of Fe to a large extent depends on soil factors. The key soil factors contributing to Fe chlorosis are parent material, soil pH, calcium carbonate content, organic matter and interaction of Fe with other nutrients.

2.4.1.1 Parent material

Most of the Fe in earth's crust is in the form of silicates. Iron released by weathering is precipitated as oxides or hydroxides, only a small portion of it is incorporated in secondary silicate mineral (Schwertmann and Taylor, 1977). Although most soils contain adequate Fe, amounts that are available to the plant are dependent on factors such as Fe species in the soils and plant genotypes (Miller *et al.*, 1984). Fe deficiency is common in calcareous soils (Miller *et al.*, 1984) but it may also occur on non

calcareous, and coarse-textured soils (Chaney, 1984).

2.4.1.2 Soil low in available Fe

Most soil in the arid and semi-arid regions in world are rich in Fe content. On an average earth crusts contains Fe to the extent of 5% by weight. However, all the Fe present in soils is not in the form which plants can use. The single most important factor responsible for Fe deficiency in plants is its low solubility of Fe(III) oxides (Lindsay, 1979) which makes it less available to plants. Soils containing less than 2.5 mg kg^{-1} DPTA extractable Fe are considered to be deficient (Sillanpaa, 1982) and often show deficiency symptoms when crops are grown on such soils.

2.4.1.3 Soil pH

The availability and uptake of nutrients by plants in soils is highly dependent on pH (Tisdale *et al.*, 1985). Solubility of Fe is highly pH dependent and the activities of Fe^{3+} and Fe^{2+} decrease by 1000-fold and 100-fold respectively, for each unit increase in pH. Under alkaline conditions Fe^{2+} is oxidized to Fe^{3+}, which is relatively unavailable to plants and precipitates as Ferric oxide ($Fe_2O_3.H_2O$), whose solubility is extremely low 10-38 M (Lindsay and Norvell, 1978). The concentration of Fe^{3+} decreases from 8-10 to 10-20 M as pH increases from 4 to 8 (Romheld and Marschner, 1986).

Sarkar and Wyonjones (1982) from their experiments on the effect of rhizosphere pH on Fe availability reported that Fe content increased with decreasing pH upto 5.5 and Fe content of both shoot and root were inversely proportional to the rhizosphere pH.

Presence of calcium carbonate ($CaCO_3$) in alkaline and sodic soils further intensified this problem (Kumar *et al.*, 1990).

2.4.1.4 Lime content in the soil

Juritz (1912) for the first time related the incidence of Fe chlorosis to the calcium carbonate content in the soils. The concentration and uptake of Fe by pea plants was reduced with increased lime application (Dahiya and Singh, 1976). High free lime content significantly decreased the pod and haulm yields of groundnut (Sutaria and Patel, 1987) due Fe chlorosis. The critical levels of total $CaCO_3$ in soil was 20 -25% and 10% for free $CaCO_3$ (active lime).

2.4.1.5 Bicarbonate content

Bicarbonate (HCO_3^-) in soil and water is an important cause for inducing Fe chlorosis (Chaney, 1984; Coulombe *et al.*, 1984). Bicarbonate ion can be formed in calcareous soils by the reaction of CO_2 and water on calcite. Poor soil moisture and accumulation of CO_2 produced by roots and microbial respiration under high soil moisture conditions enhances the accumulation of HCO_3^- in the rhizosphere to the extent of 400 to 500 ppm, which results in Fe chlorosis (Boxma, 1972; Kovanir *et al.*, 1978).

2.4.1.6 Organic matter

Available Fe in soil is primarily present as part of an organic complex. Organic matter in soils thus exerts a pronounce effect on Fe availability (Chen and Barak, 1982).

The formation of soluble Fe complexes by naturally occurring chelating ligand may enhance the solubility of Fe (Olomu *et al.*, 1973). However, heavy manuring in alkaline soils reduces the availability of Fe as it is strongly adsorbed on the surface of organic matter, but on decomposing it is slowly supplied to the plant (Wallace and Lunt, 1980).

2.4.1.7 Nutrient interactions

Iron deficiency can be induced by the interaction of Fe with various nutrient elements.

2.4.1.7.1 Nitrogen

The form of nitrogen applied may affect the availability of soil Fe. Increased uptake of NO_3-N (nitrate nitrogen) may cause an imbalance in the cation/anion ratio, resulting in exudation of HCO_3^- into the rhizosphere with a subsequent reduction in Fe uptake (Chen and Barak, 1982). Thus, high levels of NO_3-N may induce Fe chlorosis. Nitrate uptake leads to alkalization of root zone which can lower Fe solubility and availability. However NH_4-N (ammoniacal nitrogen) fertilizer produces acidity when NH_4^+ is utilized by plants (Tisdale *et al.*, 1985; Wallace and Lunt, 1980). Application of NO_3-N increased dry matter production of Fe efficient soybean cultivar (Hawkeye) and decreased in case of Fe inefficient cultivar (T-203) (Atkas and Egmond, 1979).

2.4.1.7.2 Phosphorus

High phosphorus (P) in soils is antagonistic to Fe and decreases it's availability to

plants due to the formation of insoluble Fe phosphates (Wallace and Lunt, 1980; Mandal and Haldar, 1980). Presence of high P content in the soil inhibits the absorption and transport of Fe from roots to the shoots (Elliott and Lauchli, 1985).

Low P content in the rhizosphere increased the availability of Fe to corn (Azarbadi and Marschner, 1979) and chickpea (Mehrotra *et al.*, 1988) in pot studies resulting in amelioration of Fe chlorosis. Similarly antagonistic effect of P on Fe was also observed in groundnut and blackgram (Rao *et al.*, 1988).

High P concentrations in the plant tissue may induce Fe chlorosis due to the immobilization of Fe in the veins of the leaves (Rediske and Biddulph, 1953; Brown *et al.*, 1959).

2.4.1.7.3 Potassium

An Fe efficient soybean cultivar, A 7 was unable to respond to Fe deficiency stress in the absence of K in nutrient solutions (Jolley *et al.*, 1988). The lack of a Fe deficiency stress response in the absence of K resulted in reduced levels of leaf Fe and greater chlorosis in the species. Potassium seems to play a very specific role in the plant for maximum utilization of Fe (Moraghan and Mascagni, 1991).

2.4.1.7.4 Zinc

Zinc interacts with Fe in the same way as P. An inverse relationship exits between Zn and Fe. Zn deficiency increases Fe uptake in certain plant species (Francois and Goodin, 1972), some times to toxic level (Adams and Pearson, 1967). When pH of a

selected soil was increased from 5.2 to 7.1 by lime addition, cotton became Zn deficient and accumulated high levels of Fe (Brown and Jones, 1977). Zn application decreased Fe concentration in rice shoots and roots (Haldar and Mandal, 1981).

2.4.1.7.5 Manganese

The interaction between Fe and Manganese (Mn) has been extensively studied, but it is not well understood. Zaharieva *et al.*(1988) suggested that (i) Fe hampers Mn uptake and (ii) Mn decreases plant Fe^{2+} and adversely affects Fe metabolism. In rice plants the translocation of Fe from roots surfaces intensified with increasing Mn concentration, part of the reduced Fe levels in shoots was attributed to the formation of insoluble Mn oxides on the roots (Kuo and Mikkleson, 1981).

2.4.1.7.6 Molybdenum

Increase in Molybdenum (Mo) decreased Fe uptake, this interaction is important in alkaline soils where Fe availability is low and soluble MoO_4^{2-} content is high (Olsen and Watanabe, 1979).

2.4.2 Environmental factors

Climatic factors greatly influence the occurrence of Fe deficiency in plants under field conditions. Temperature, light and soil moisture content may adversely affect the uptake and metabolism of micronutrients by plants.

2.4.2.1 Temperature

Since Fe absorption and translocation from root to shoots is an active process (Branton and Jacobson, 1962), temperature influences the occurrence of Fe deficiency. Temperature changes may either enhance or suppress Fe chlorosis, depending upon the situation. In general, soil temperature has less effect on Fe chlorosis in plant possessing the Strategy II type of Fe stress response than in those possessing the Strategy I type (Romheld and Marschner, 1986).

Temperature could influence the severity of Fe deficiency in plants growing in soils in following ways:

a. low temperature reduces root growth and metabolic activity, and the Fe stress response in non-graminaceous plants (Marschner *et al.*, 1986).

b. low soil temperature could reduce the production of phytosiderophores, and the resultant mobilization and uptake of soil Fe by members of the Gramineae .

c. high soil temperature decreases Fe uptake of monocots by increasing microbial decomposition of photosiderophores (Awad *et al.*, 1988).

d. low soil temperature could increase HCO_3^- levels in the soil and severity of Fe chlorosis by increasing the solubility of CO_2 in soils (Inskeep and Bloom, 1986).

e. high soil temperature could increase HCO_3^- level and Fe chlorosis by stimulating microbial activity and CO_2 production (Inskeep and Bloom, 1986).

f. high soil/aerial temperatures could stimulate relative growth rates and induce Fe deficiency (Inskeep and Bloom, 1986).

g. high soil temperature could increase the uptake of P by plants and induce Fe chlorosis (Riekels and Lingle, 1966; Moraghan, 1987).

h. low soil temperature retards plant growth and the supply of Fe to plants may be reduced thus aggravating Fe chlorosis (Wallace and Lunt, 1980).

2.4.2.2 High light intensities

High light intensities are known to induce Fe chlorosis (Wallace and Lunt, 1980)

2.4.2.3 Soil moisture

High soil moisture has a strong effect on Fe chlorosis through its effect on plant metabolism. Many reports indicated that excess irrigation or prolonged wet periods result in Fe chlorosis particularly in dicot with Strategy I type, as a result of building up of HCO_3^- in calcareous soils (Chaney, 1984), presumably due to the minor effect on HCO_3^- on this type of response (Romheld and Marschner, 1986; Yen *et al.*, 1988). Increased Fe chlorosis in plants subsequent to irrigation is sometimes due to high levels of HCO_3^- in added water (Harley and Lindner, 1945). In addition high HCO_3^-, high pH and low Fe content in poorly aerated soils caused due to excess water destroy many of the smaller roots and reduce the absorptive capacity of the whole root system (Lindsay, 1984) which may induce Fe chlorosis.

Oxidation potential increases with increasing aeration and this increased oxidation potential leads to conversion of Fe^{2+} to Fe^{3+} and thus decreases its availability (Ponnamperuma, 1972). High soil moisture, poor aeration, and cool temperature disturb

plant metabolism due to which Fe is inactivated (Burtch *et al.*, 1948). Zaharieva and Romheld (1991) reported that the relationship between H/OH^- ion release and Fe nutrition of groundnut plants is complex under soil conditions and depends on soil parameters including $CaCO_3$ contents and that even by enhanced H^+ release Fe nutrition could be impaired if soils $CaCO_3$ is too high. Most of the plants often suffer from Fe chlorosis under high moisture conditions but plant turn to green if soils are dry (Burtch *et al.*, 1948, Chaney and Coulombe, 1982; Wallace *et al.*, 1976). In a field study it was observed that excess irrigation increased chlorosis by 23.5 % in groundnut and application of $FeSO_4$ showed 29.4 % recovery of chlorosis (Singh *et al.*, 1987).

2.4.2.4 Soil erosion

Removal of top soil, erosion or land levelling leads to exposure of Fe deficient subsoils, crops in such soils may suffer from Fe chlorosis (Katyal and Randhawa, 1983).

2.4.3 Plant factors

Different species and even cultivars of a species vary in their susceptibility to Fe deficiency. The various plant factors which influence the Fe deficiency are briefly reviewed hereunder.

2.4.3.1 Genotypic differences

Plant species differ qualitatively in their reactions to Fe deficiency. The ability or lack of the genotype to absorb and translocate Fe has been reported by many workers

(Brown and Ambler 1970; Brown and Bell 1969; Wallihan and Garber, 1968; Wutscher *et al.*, 1970).

Fe efficient species respond well to Fe deficiency by some distinct biochemical changes in the roots which leads to enhanced mobilization and uptake of Fe, whereas Fe inefficient species do not have these responses (Brown, 1979). These Fe efficient species have the tendency to lower the pH of the medium in which they are grown and increase reducing capacity of roots due to accumulation of phenols (Brown and Ambler, 1974; Romheld and Marschner, 1981). These reactions are induced specifically by Fe deficiency and enable Fe efficient species to take up the Fe at a higher rate (Brown and Ambler, 1974). Romheld *et al.* (1982) observed typical responses such as increased formation of roots hairs, development of rhizodermal transfer cells and increased capacity to reduce Fe^{3+} in the roots of Fe efficient plant species under Fe deficiency.

The differential plant responses to Fe deficiency conditions may be due to its better Fe absorption by root system, translocation within the plant, and utilization of Fe within leaves. Brown (1961) indicated that the cultivars differed in root absorption of Fe because of different efficiencies in reduction of Fe prior to its uptake. Plants were classified as Fe efficient if they respond to Fe stress and induce biochemical reactions that make Fe available for use in the plant and Fe inefficient, if they do not. Several plant factors which contribute to the efficiency of Fe utilization (Brown *et al.*, 1961) are:

a. exudation of H^+ ions into the medium,

b. excretion of reducing compounds from the root, and

c. reduction of Fe^{3+} to Fe^{2+} at the root surface.

The main difference between plants is due to the NO_3^+ metabolism and H^+ or OH^- excretion. In the efficient plants when Fe stress develops, uptake of NO_3^+ decreases, and plant take up more cations than anions and a proton is released from the roots. This proton excretion stimulates the reduction of Fe^{3+} to Fe^{2+}, mobilizes enough Fe^{2+} near the roots surface that is taken up by the plant which regain its NO_3^- uptake. This is a cyclic response and when the NO_3^- is depleted H^+ excretion continues (Hauba *et al.*, 1971).

The efficient H^+ excretion during NH_4^+ uptake raised the hypothesis that if Fe inefficient plants would be able to take up NH_4^+ the Fe chlorosis could be eliminated or reduced. The most practical way to prevent nitrification of NH_4^+ in the soil is through the use of nitrification inhibitors (Bundy and Bremner, 1973).

Vanegmond and Aktas (1977) suggested that Fe efficient plants are those which normally release relatively low amounts of hydroxyl ions and respond to Fe stress by lowering the pH of the nutrient medium and decreasing anion uptake, but Fe inefficient plants are those which normally excrete relatively high amounts of hydroxyl ions which continue to increase the pH of the nutrient medium under Fe stress.

Iron efficient plants respond to Fe deficiency stress by inducing Fe solubilizing reactions at or near the root surface (Olsen and Brown, 1980). They noticed that roots of dicotyledonous species reduced much about twice as much Fe^{3+} as equal weights of monocotyledonous species. Iron efficient tomato, soybean and oats roots reduced more Fe^{3+} than roots of the Fe inefficient varieties.

2.4.3.2 Cropping systems

Cropping systems like maize-wheat, cotton-wheat, maize-potato, wheat-sugarcane, potato-wheat on coarse and medium textured, alkaline and calcareous soils deplete the soil Fe and cause Fe deficiency (Kumar *et al.*, 1990).

2.4.3.3 Root damage

Root damage by flooding, nematodes or other organisms may induce Fe chlorosis (Wallace and Lunt, 1980). Absorption of Fe by plants is largely restricted to actively growing root tips (Clarkson and Sanderson, 1978). Therefore, restricted root growth in dry surface layers, the soil zone with the largest amount of available Fe may induce Fe chlorosis.

2.4.3.4 Virus

Virus infection in plants may induce Fe chlorosis (Wallace and Lunt, 1980).

2.5 Management practices for Fe chlorosis

The various management practices for prevention and correction of Fe deficiency in plants have reviewed (Parkpian *et al.*, 1988; Hagstrom, 1984; Mortvedt, 1986; Fehr, 1984; and Mortvedt, 1991). Some of the important practices adopted to alleviate Fe deficiency are soil amendments, foliar application of Fe compounds, genotypic selections, and other management practices (Chen, 1993).

2.5.1 Soil additives

Soil additives for the control of Fe chlorosis have been categorized as 1) inorganic Fe salts, 2) Fe chelates, 3) organic compounds, 4) acidifying soil amendments, and 5) industrial by products and wastes (Hagstrom, 1984).

2.5.1.1 Inorganic Fe compounds

The most common inorganic source of Fe is $FeSO_4$. Soil application of inorganic $FeSO_4$ caused a significant increase in the leaf chlorophyll content and Fe concentration there by reducing Fe chlorosis in sorghum (Olson, 1950) and peaches (Razeto, 1982). Ryan and Stroehlein (1976) observed increased yield of sorghum to heavy application rates of $FeSO_4.7H_2O$ in Fe deficient soils. Mortvedt and Giordano (1973) also studied fertilizers containing various mixtures of ferrous sulfate, ammonium polyphosphate and ammonium thiosulphate, and found that band application of $FeSO_4$ plus polyphosphate increased yield and Fe uptake of sorghum by 200% over the application of polyphosphate alone.

Soil application of inorganic Fe sources usually are not effective in supplying Fe for crops unless very high doses are applied which is not economical for most of the field crops (Mortvedt, 1991). Soil application of $FeSO_4$ was ineffective in correcting Fe deficiency in peanuts at the rate of 20 kg ha^{-1} (Suwanarat and Suwanarit, 1986), but pod yield was increased by 50% when applied at a rate of 625 kg ha^{-1} (Kumarohita *et al.*, 1966). Inorganic Fe sources get rapidly converted to forms which are not available to plants, especially in calcareous soils. Therefore, band application of Fe is more effective

than broadcasting, since soil fertilizer contact is limited (Mortvedt, 1986).

2.5.1.2 Iron chelates

The term "chelate" refers to chemicals which surround certain micronutrients, protecting them from being rendered unavailable by high content of Ca or other elements. It is generally observed that soil application of chelated compounds are more effective than inorganic ion salts in correcting Fe chlorosis (Hagstrom, 1984). Iron chelates were shown to be efficient sources as early as 1950's. Ferrous salts of ethylene diamine tetra acetic acid (FeEDTA) was used to supply Fe to several plants in nutrient solutions (Jacobson, 1951) and under field conditions. Later many experiments were conducted to study the various chelating agents for correcting chlorosis (Wallace *et al.*, 1955; Holmes and Brown, 1955; Chen and Barak 1982).

Some Fe chelates which are used as Fe sources are ferric ethylene diamine tetra acetic acid (FeEDTA) and its hydroxy form (FeHEDTA), ferric ethylene triamine pentaacetic acid (FeDTPA), and ferric ethylene diamine di (o-hydroxy phenylacetic acetate) (FeEDDHA), and more recently methylated isomer of FeEDDHA (FeEDDHMA). It has been reported that application of FeEDTA at 31 kg ha^{-1} (Kumarohita *et al.*, 1966) and FeEDTA at 50 kg ha^{-1} (Suwanarat and Suwanarit, 1986) increased yield of peanut cv. Tainan 9 and SK38, respectively on Takli soils series. The chelating agent FeEDDHA has been the most effective Fe chelate for correction of Fe chlorosis for over the last thirty years, but it is too expensive for general use except for ornamental and high value crops (Wallace, 1991; Wallace and Wallace, 1992).

2.5.1.3 Organic compounds

Organic materials as carriers of Fe have been widely discussed by Chen *et al.* (1982). The use of organic materials in correction of Fe chlorosis is reviewed by Hagstrom (1984). Organic material such as plant residues, manures, sewage sludge, peat, charcoal, by-products of forest products manufacturing (polyflavonoids and lignosulfonates) and even coal have also been showed to be effective in alleviating Fe chlorosis. Organic materials as paletted manures (Thomas and Mathers, 1979) and air dried organic matter (Parsa and Wallace, 1979) were effective in reducing Fe chlorosis and increasing sorghum yields. Iron enriched peat (3.7% Fe) was effective in reducing symptoms of chlorosis and increasing yield of peanuts in Israel (Chen *et al.*, 1982). Similar results were obtained by application of FYM to rice in India (Swarup, 1982). Hagstrom (1984), reported that spraying of $FeSO_4$ solution on plant stubbles with subsequent soil incorporation could prove to be a relatively inexpensive and simple procedure in alleviating Fe chlorosis.

2.5.1.4 Acidifying soil amendments

One of the ways to increase the availability of Fe in the soil is to reduce the pH of the soil. Soil amelioration to prevent Fe chlorosis by acidification of the entire root zone is impractical (Hagstrom, 1984). Therefore only a part of the soil near the root zone can be acidified by the application of H_2SO_4 which can ameliorate Fe chlorosis (Wallace et al., 1976a). In addition the band application of acid waste sulphur (Wallace *et al.*, 1982) was

effective in preventing lime-induced Fe chlorosis. The amount of the acidulating material required may vary with the percent $CaCO_3$ present in the soils.

2.5.1.5 Industrial by-products and wastes

Industrial waste materials such as waste pyrites from Colarodo mining operations (Wallace *et al.*, 1976b) and waste products of high grade Fe sources (Wallace *et al.*, 1976c) were effective in correcting Fe chlorosis in soybean and corn in U.S.A. Similar results were obtained by Vlek and Lindsay (1978).

2.5.1.6 Potassium salts

The ability of potassium and $FeSO_4$ to improve Fe nutrition is well known (Barak and Chen, 1984). Since K is a rapidly absorbed cation by plant roots, there is considerable net H^+ afflux with K fertilization which improves the availability of Fe to plants; H^+ afflux is part of the deficiency mechanism , especially for dicot plants (Wallace, 1991; Jolley *et al.*, 1988). Inclusion of K_2SO_4 with $FeSO_4$ has resulted in correction of Fe chlorosis of peanuts on a highly calcareous soil and increased chlorophyll content in leaves and higher dry matter yields (Shaviv and Hagin, 1987).

2.5.2 Foliar management

As soil applications of most Fe sources generally are ineffective for crops, foliar spray applications are widely used to correct Fe chlorosis. Both inorganic and organic Fe sources are effective as foliar sprays (Mortvedt, 1991; Mortvedt, 1986).

Spraying of 0.5% FeSO4 solution with 0.25% Tween 80 at weekly intervals commencing 10 days after emergence produced higher yield of peanut pods than spraying at 15 days intervals or greater. Spraying plants on nine occasions at weekly intervals increased peanut kernel yield from 162 kg ha^{-1} to 975 kg ha^{-1} (Ratanarat *et al.*, 1987).

Foliar application of iron sulphate (0.5%) and citric acid (0.02%) was effective in controlling Fe chlorosis and resulted in higher pod and haulm yield in groundnut (Singh and Dayal, 1992). Similar results were obtained with iron sulfate on groundnut (Potdar and Anders, 1992, 1993).

2.5.3 Genotype selection

Ratanarat *et al.* (1987) screened peanut cultivars on the Takli series soils and found that Fe chlorosis was evident in all 20 cultivars examined. However, there was useful variation in the degree of Fe chlorosis such that low chlorosis scores at 30 and 50 days after emergence were inversely related to kernel yield at maturity. These results suggest the potential for selecting more Fe efficient peanut cultivars than those grown currently. Kannan (1982) tested eleven peanut cultivars for their relative tolerance to Fe stress and found that TG 1 and TG 7 were tolerant to Fe stress conditions by reducing the pH to 3.7 and 4.7, respectively. Similarly JL 24, SB XI and TG 3 also reduced rhizosphere pH but did not recover from the Fe stress completely.

Reddy (1983) while screening the groundnut genotypes for Fe stress found that cv. Robout 33-1 was efficient in utilization of Fe under deficient conditions. Jolley *et al.*

(1987) studied the response of four peanut cultivars which varied in their response to Fe chlorosis in the field and in the growth chambers and found that 71-234 and 71-238 were resistant to Fe stress. Selection of Fe efficient genotypes proves to be the best, and cost effective method to control Fe chlorosis (Parkpian *et al.*, 1988).

Reddy *et al.* (1993) evaluated twenty different groundnut genotypes, based on visual deficiency symptoms (chlorosis score), and classified the genotypes into three groups. Efficient (no genotype was found to be efficient), moderately efficient (TCGS 273, TCGS 2, TCGS 3 and Kadiri 3), and inefficient (TCGS 1, TCGS 7, TCGS 11, TCGS 26, TCGS 28, TCGS 29, TCGS 30, TCGS 1518, TPT 1, TPT 2, ICGS 11, ICGS 44, Girnar, JL 24, ICGS(E) 21 and TMV 2). Similarly, Singh and Vidya Chaudhari (1991) screened several groundnut varieties tolerant to Fe chlorosis and reported many varieties including TMV 2 and ICGS 11 to be susceptible to Fe chlorosis.

2.5.4 Other management practices

2.5.4.1 Irrigation practice and soil aeration

Excessive irrigation and poor soil aeration is one of the important causes inducing Fe chlorosis (Wallace and Lunt, 1980; Chen and Barak, 1982). Proper irrigation management i.e., controlled irrigation without flooding the field could alleviate Fe chlorosis specially in calcareous soils.

Growing of groundnut on broad-bed and furrow (BBF) system was found beneficial in decreasing Fe chlorosis (Potdar and Anders, 1992). It may be due to better soil aeration which facilitated higher uptake of Fe by roots of groundnut.

The addition of Fe chelates, especially Fe EDDHA to drip irrigations has been studied (Wallace and Wallace, 1983), but it is used little because of its high cost. Since drip irrigation is widely used in high value crops, often trees and vines , 2 to 5 kg ha^{-1} FeEDDHA should be economical (Wallace, 1991).

2.5.4.2 Tree injection methods

Injection of trees trunks with solution of Fe sources have been reported to control Fe chlorosis in many woody plants (Wallace and Wallace, 1986b).

2.5.4.3 Siderophores

Jurkevitch *et al.*(1988) concluded from their studies that bacterial siderophores may serve as a remedy to lime induced chlorosis in groundnut plants grown in calcareous soils.

2.6 Effect of Fe on plant growth and development

Iron is an essential nutrient for all crop plants and any factor which impairs the absorption and translocation of Fe causes chlorosis and ultimately reduces the plant growth. It has been observed that phytomass of roots stems and leaves of mustard plants decreased due to Fe deficiency created by high bicarbonate contents (Dekock, 1955). In sunflower crop also Fe deficiency decreased plant height, leaf area and dry matter production (Djendor, 1972), and yield (Dahiya and Singh, 1976).

Rao *et al.* (1988) found that the Fe deficiency had profound impact on reducing the stem growth in groundnut. They also reported that root phytomass decreased due to Fe deficiency. Iron deficiency reduced dry weights of leaves, stem, and whole plant in groundnut and black gram (Rao and Narayanan, 1990).

2.7 Yield losses due to Fe chlorosis in groundnut

Iron chlorosis can result in severe yield losses in groundnut. Young (1967) reported that mild chlorosis apparently did not decrease peanut yields; moderate chlorosis decreased yields by about 20% and severe chlorosis decreased peanut yields by about 50%. Singh *et al.* (1989) reported that three foliar Fe sprays increased 43% pod and 35% haulm yield. Similarly, Bhaskar (1990) indicated that foliar Fe sprays increased groundnut yield by 53% in Anantapur district of Andhra Pradesh. Recent results from on-farm trials in Andhra Pradesh and Maharashtra indicated that Fe chlorosis can cause yield losses upto 32% pod, 18% haulm, and 25% total dry matter production in groundnut (Potdar and Anders, 1993).

2.8 Summary

Iron chlorosis in groundnut is one of the major nutritional disorders commonly associated with calcareous soils, causing significant yield losses in many field crops. The importance of Fe nutrition in plants has been discussed by Brown (1961); Chen and Barak (1982) and Vose (1982).

The various factors responsible for Fe deficiency are low soil Fe, high soil pH, excess free $CaCO_3$, high HCO_3^-, excess soil moisture, poor drainage, high amounts of heavy metals, high soil P, temperature extremes, heavy manuring (alkaline soils), low organic matter (acidic soils), genotypic differences, and root damage. The problem can be further aggravated by interactions of Fe with the above mentioned factors.

Various techniques have been suggested for diagnosing Fe deficiency based on visual deficiency symptoms, plant analysis, and soil analysis. These techniques are discussed in detail by Parkipian *et al.*,(1988) and Chaney (1984). Soil analysis for DTPA extractable Fe is considered to be a satisfactory measure of Fe availability to the plants. Extractable Fe content in the fresh leaf tissue is found to be positively correlated with the leaf chlorophyll content and negatively correlated with the severity of chlorosis. Therefore, extractable leaf Fe content seems to be a better indicator of Fe deficiency than the DTPA soil Fe. Total leaf Fe content was found not related to the incidence of Fe chlorosis. However, under on-farm conditions visual chlorosis rating systems was found effective, rapid and inexpensive tool for diagnosing the incidence of Fe chlorosis.

Plant species and genotypes vary considerably in their tolerance to Fe chlorosis. The mechanisms for Fe tolerance in plant species have been discussed in several reviews (Brown and Jones, 1976; Clark and Gross, 1986; Marschner, 1986). Identifying Fe efficient genotypes and modifying Fe inefficient genotypes by crop improvement are the best strategies to overcome this problem. Such information is lacking in groundnut. However, some progress has been made in screening groundnut genotypes for Fe chlorosis (Singh and Vidya Chaudhari, 1991; Reddy *et al.*, 1993).

The correction methods for Fe chlorosis have been discussed by Mortvedt (1991); Wallace (1991); Mortvedt (1986); Hagstrom (1984); Fehr (1984); Parkipian (1988). Among the various methods of correcting Fe chlorosis, soil application of inorganic salts in many cases were ineffective due to rapid conversion of available Fe into non available form. Application of chelated Fe was effective in alleviating Fe deficiency but its use has been restricted to high value crops because of high fertilizer cost. The foliar application of iron sulphate with a suitable surfactant was the most effective way of correcting Fe deficiency in many field crops including groundnut. However, development of Fe efficient cultivars appears to be the best long-term solution to this nutritional disorder.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

This chapter describes materials used and procedures adopted in data collection and analysis of village surveys and on-farm experiment.

3.1 Village surveys

3.1.1 Location and selection of villages

Two contrasting villages namely Kottapeta and Pasupalla in Kurnool district of Andhra Pradesh were selected for this study after a preliminary survey of the district. Groundnut is predominantly grown in these villages and it often suffers from iron chlorosis. Both villages varied for soil type, sowing season, and irrigation practice. The characteristics of the villages are given in Table 1.

Table 1. Characteristics of the villages surveyed in Kurnool district of Andhra Pradesh, 1992-93.

Village	Soil type	Groundnut sowing season	Irrigation source
Kottapeta	Vertisol	Rainy season (Kharif)	Bore wells
		Postrainy season (Rabi)	Bore wells
Pasupalla	Sandy loam	Postrainy season (Rabi)	Bore wells

The staff from Krishi Vigyana Kendra at Banaganpalle, Regional Agricultural Research Station at Nandyal, and ICAR (Indian Council of Agricultural Research) Transfer of Technology Unit at CRIDA (Central Research Institute for Dryland Agriculture), Hyderabad, assisted in identifying these villages.

3.1.2 Selection of respondents

A complete list of farmers in each village was obtained and arranged in ascending order of their landholding, and then divided into three equal parts and each designated as small, medium, and large landholding group. From each group, 10 farmers were randomly selected for detailed surveys. Number of households in each village and range of landholding in each group are given in Table 2.

Table 2. Landholding characteristics of farmers in Kottapeta and Pasupalla villages in Kurnool district of Andhra Pradesh, 1992-93.

Village	No. of household	Landholding range (Acres)		
		Small	Medium	Large
Kottapeta	554	< 3.1	3.1 - 7.4	> 7.4
Pasupalla	158	< 2.7	2.4 - 4.6	> 4.6

3.1.3 Farmer interviews and data collection

Data were collected from the selected respondents by using the interview schedule developed for this purpose. The interview schedule was designed to collect information on farmer resources, conventional and current crop management practices, perceptions and management strategies for iron chlorosis in groundnut (Appendix I). Economics Group, Resource Management Program of ICRISAT assisted in formulating the interview schedule.

The interviews were conducted in local language (Telugu) and the investigator was well aware of the farmers circumstances in survey villages. Interviews were generally conducted in the early mornings/evenings at the time and place convenient to farmers.

3.1.3.1 Pre-testing interview schedule

The suitability of interview schedule was pre-tested among respondents in each group by conducting individual interviews. Based on the experience gained in the pretesting the interview schedule was modified.

3.1.3.2 Establishing rapport with the farmers

Prior to actual data collection, informal rapport was established with the respondents during preliminary field investigations with the help of extension personnel from the Krishi Vigyan Kendra (KVK), progressive farmers and local leaders. The preliminary discussion and field visits gave overall knowledge of farmer's current production technology for groundnut cultivation. The respondents were explained about

the purpose of this study. This approach helped in successful completion of these surveys.

3.1.3.3 Data collection

Individual interviews of selected respondents were conducted by the investigator with the help of local KVK staff. In each interview, while the investigator was interviewing the other staff recorded the data.

3.1.3.4 Data coding and analysis

Qualitative data were coded, statistically analyzed, and summarized as percent frequencies for each of the questions. Whereas, the quantitative data were presented as mean values.

3.2 On-farm experiment

A **"researcher-managed"** on-farm diagnostic study on Iron chlorosis in groundnut was conducted at an iron chlorotic site in Kurnool district of Andhra Pradesh during the postrainy season of 1992-93. The details of the present investigation are as follows:

3.2.1 Experimental site

An iron chlorotic site in the Farm of Mr. B. Venkataswamy, located in Kottapeta village in Banaganpalle mandal of Kurnool district, was selected for the present experiment.

3.2.2 Weather conditions

Kottapeta village is situated in the semi-arid tropical region of Andhra Pradesh. Meteorological data pertaining to rainfall, minimum and maximum temperatures, relative humidity and hours of sunshine recorded during the experimental period were collected from the nearest meteorological observatory located at Nandyal, and are depicted in Fig. 1a and b. The mean minimum and maximum temperatures during the experimental period was 22.22°C and 35.95°C, respectively. The mean relative humidity at 7.17 hr and 14.17 hrs during the experimental period was 72.97 % and 35.74 %, respectively. The mean number of sunshine hours was 9.47.

3.2.3 Cropping history

Details of the cropping history of the experimental field during the preceding two years are presented in Table 3.

Table 3. Cropping history of the experimental site

Years	Season	Crop	Irrigation source
1991-92	Rainy	Groundnut	Rainfed
	Postrainy	Paddy	Bore wells
1992-93	Rainy	Groundnut	Rainfed
	Postrainy	Groundnut (present study)	Bore wells

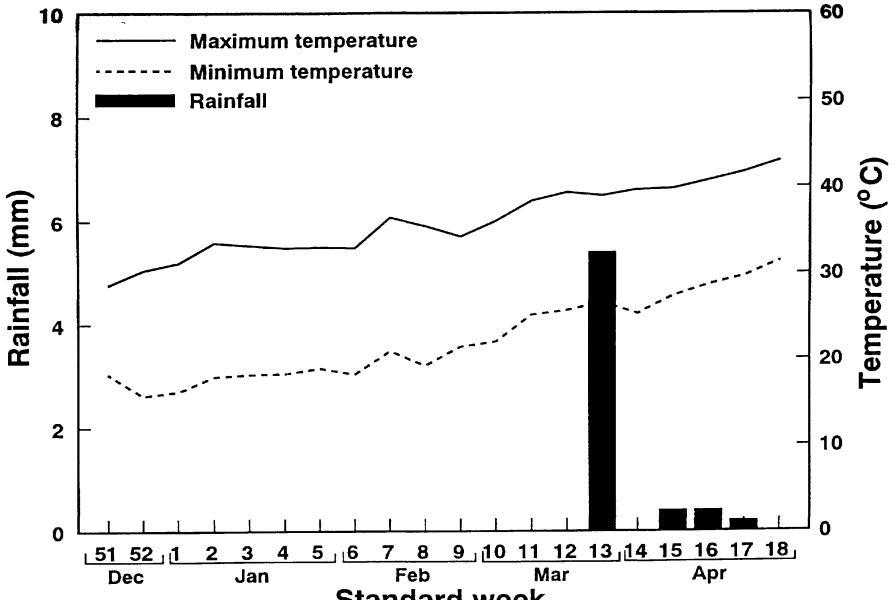


Figure 1a. Mean minimum and maximum tempeartures and rainfall recorded during the experimental period, 1992/93.

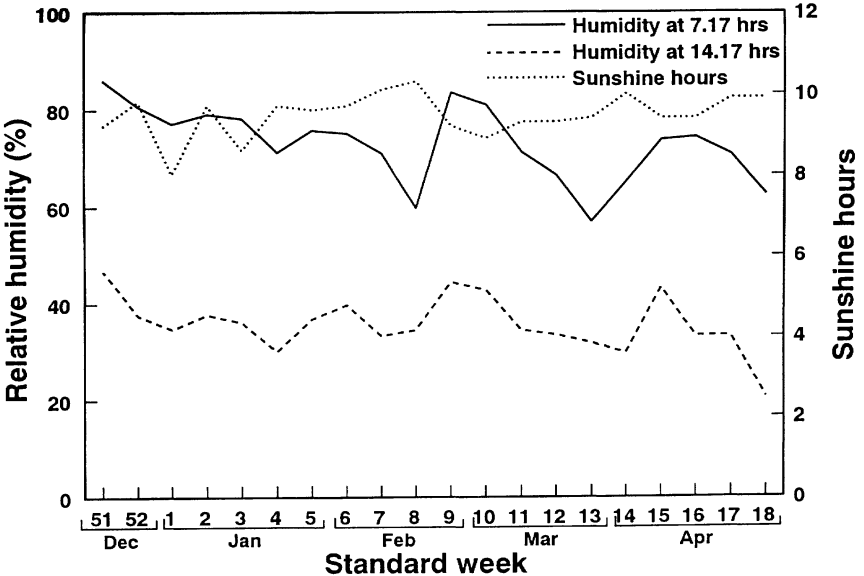


Figure 1b. Mean relative humidity and sunshine hours recorded during the experimental period, 1992/93.

3.2.4 Soil and irrigation water

The soil of the experimental site was a deep Vertisol with a long history of iron chlorosis. Composite soil samples collected prior to sowing from 0-15 cm depth were analyzed for physical and chemical properties (Table 4a). Water samples were also analyzed for chemical properties (Table 4b).

3.2.4.1 Soil physical properties

Mechanical composition of the soil was determined by using a Bouyoucos hydrometer method (Bouyoucos, 1962).

3.2.4.2 Soil chemical analysis

Soil pH was measured by a glass electrode, a calomel reference electrode and pH meter (Mocel LI-10). Salt content was measured by using electrical conductivity bridge (YSI Model 32). Both the measurements were made on 1:2 soil:water suspension as described by Jackson (1967). Soil organic carbon was determined by Walkely-Black method (Allison, 1965).

Total Nitrogen was determined by modified Kjeldahl method (Jackson, 1967). Mineralizable nitrogen was determined by using 2N KCl solution for extraction as described by Keeny and Nelson (1982), and available phosphorous by method as described by Olsen and Dean (1965). Available iron, copper, manganese, and zinc were determined by DTPA (Diethylene triamine penta acetic acid) extraction (Lindsay and Norvell, 1969).

Table 4a. Characteristics of the soil at the experimental site

Characteristics	Content
Particle size distribution (%)	
Sand (2-0.02mm)	43.72
Silt (0.02- 0.002mm)	20.87
Clay (< 0.002mm)	34.42
Chemical properties	
pH (1:2 soil water suspension)	8.52
EC (1:2 soil water suspension)(mmho cm^{-1})	0.57
CEC (milli mhos 100 g^{-1} soil)	42.34
Calcium carbonate (%)	10.75
Organic carbon (%)	0.57
Total nitrogen (ppm)	563
Available nitrogen (ppm)	17.9
Available phosphorus (ppm)	7.50
Exchangeable nutrients (ppm)	
Potassium	250
Calcium	4455
Magnesium	1209
Sodium	700
DTPA Extractable nutrients (ppm)	
Iron	6.94
Zinc	0.44
Copper	0.84
Manganese	18.21

Table 4b. Chemical composition of irrigation water used at the experimental site.

Characteristics	Content
pH	7.53
EC (mmho cm^{-1})	2.00
Carbonate (meq/l)	0
Bicarbonate (meq/l)	6.76
Calcium (meq/l)	5.35
Magnesium (meq/l)	3.55
Potassium (meq/l)	0.06
Sodium (meq/l)	10.97

Exchangeable potassium was determined by using an atomic absorption spectrophotometer after extracting the soil with neutral 1N ammonium acetate as described by Jackson, (1967). Cation exchange capacity (CEC) was determined by the sodium acetate (pH 8.2) method as outlined by Jackson (1967).

3.2.5 Experimental details

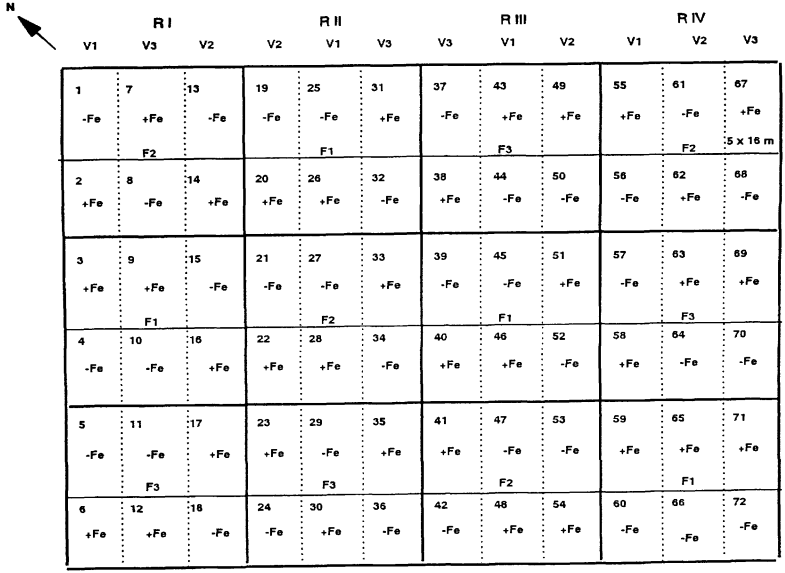
3.2.5.1 Layout of the experiment

The experiment was laid out in a strip-split plot design with four replications. Gross and net plot sizes for each sub-plot were 5 x 8 m and 3.3 x 6 m, respectively. The detailed experimental layout is shown in Figure 2.

3.2.5.2 Treatment details

Three genotypes (vertical plots) and three fertilizer practices (horizontal plots) were allocated to main plots and two iron sprays to sub-plots. The details of treatment are furnished below:

Groundnut genotypes (G)	:	TMV 2 (V1), ICGS 11 (V2), ICGV 86031 (V3).
Fertilizer practices (F)	:	No fertilizer control (F1)
		Farmers fertilizer practice (F2)
		Recommended fertilizer practice (F3)
Iron sprays (Fe)	:	Nonsprayed control (-Fe)
		Foliar $FeSO_4$ sprays (+Fe)



F1 = No fertilizer control, F2 = Farmer practice, F3 = Recommended practice
V1=TMV 2, V2=ICGS 11, V3=ICGS 86031, +Fe=Foliar Fe sprays, -Fe=No Fe sprays

Figure 2. Layout of the experimental plots at Kottapeta village in Kurnool district of Andhra Pradesh, 1992-93.

3.2.5.2. Genotype description

The characteristics of the three groundnut genotypes used in the present study are described below:

TMV 2 is spanish bunch type, with light green color foliage, small to medium size pod without beak. It is most suited for summer season and has a shelling turn over of 76% and oil content of 49.7%. The crop duration is about 100-105 days. This is the most popular and widely grown variety in Andhra Pradesh, but is highly susceptible to iron chlorosis.

ICGS 11 is spanish type, has decumbent 2 growth habit with sequential flowering and has dark green foliage. Pods are small to medium sized, without beak, two seeded tan colored seed, with a shelling turnover of 70%, 49% oil content, and 22% protein. It is tolerant to bud necrosis under field conditions. The crop duration is about 130-135 days. This high yielding genotype has been recommended for rabi cultivation in Andhra Pradesh.

ICGV 86031 is spanish type, has an erect habit with sequential flowering and elliptic dark green waxy leaves, medium size pod with none to slight beak, two seeded pod with rose tan color seed. It has shelling turnover of 66%, 52% oil, and 20% protein. It is high yielding line with multiple resistance or tolerance to spodoptera, leaf minor, jassid, and thrips, bud necrosis and iron chlorosis under field conditions. It matures in about 110 days in rainy season and 130 days during postrainy season (ICRISAT PMD No 32; Potdar and Anders, 1993).

3.2.6 Crop management practices

3.2.6.1 Field preparation

The field was prepared by single ploughing immediately after harvest of rainy season groundnut followed by harrowing twice.

3.2.6.2 Seeds and sowing

Bold and healthy kernels were selected and treated with Dithane M 45 at @ 3 g kg^{-1} seed to protect from seed-borne diseases. Crop was sown on 15 December 1992 at 30 x 10 cm spacing. Sowing was done by hand dibbling two seeds each hill at a depth of about 5-cm.

3.2.6.3 Fertilizer application

Details of the fertilizer schedule, fertilizer types and rates used, and the quantity of nutrients applied are presented in Table 5. No fertilizer control plots (F_1) received no NPK fertilizers or organic manure, Farmers fertilizer practice (F_2) received 126 kg N + 199 kg P_2O_5 ha^{-1} applied in three split doses (basal + 2 top dressings at 40 and 60 DAS), and the Recommended fertilizer practice (F_3) received 30:50:30 kg NPK ha^{-1}, all applied as a basal dose. Nutrient doses were supplied through Ammonium phosphate (28:28), Diammonium phosphate (DAP), and Muriate of potash (60% K). Fertilizers were applied by broadcasting method followed by harrowing after basal application and irrigation immediately after each top dressing. In farmer fertilizer practice, DAP was used for top dressings.

Table 5. Details of fertilizer schedule, sources, and quantity of nutrients applied in different fertilizer treatments.

Fertilizer practice	Time of application	Source of fertilizer	Amount of fertilizer (kg ha^{-1})	Amount of nutrient supplied (kg ha^{-1})		
				N	P_2O_5	K
F1	-	-	-	0	0	0
F2	Basal dose	DAP	150	27	69	-
		AP	100	28	28	-
	Top dressing at 40 DAS	DAP	200	36	96	-
	Top dressing at 60 DAS	DAP	200	36	96	-
			Total	126	199	-
F3	Basal	DAP	110	20	50	-
		MOP	50	-	-	30
			Total	20	50	30

F 1 : No fertilizer control
F 2 : Farmers fertilizer practice
F 3 : Recommended fertilizer practice
AP : Ammonium phosphate (28:28:0)
DAP : Diammonium phosphate (18:46:0)
MOP : Muriate of potash (0:0:60)

A commercial grade iron sulphate ($FeSO_4.7H_2O$) was used for foliar iron sprays. An aqueous solution of 0.5% $FeSO_4$ (W/v) with 2 ml/l of teepol as surfactant was foliar applied at 40, 60 and 90 DAS.

3.2.6.4 Gap filling

Gap filling was done at 15 DAS to maintain the uniform plant population. Gap filling was essential only for ICGS 11 and ICGV 83031 but not for TMV 2.

3.2.6.5 Plant protection

Crop was kept weed-free by hand weedings done thrice at 20, 40 and 60 DAS. Initial two hand weedings were followed by an intercultivation with Gorru.

Crop was sprayed with Monocrotophos (0.05%) twice at 60 and 90 DAS for control of leaf webber and jassids. In addition, Bavistin (0.07%) was sprayed at 90 DAS for control of rust. In general, the crop did not suffer from any pest or diseases.

3.2.6.6 Irrigation

The crop was irrigated immediately after sowing, and the subsequent irrigations were provided at 41, 61, 92 DAS and a week before final harvest. Irrigation was given by a strip irrigation method.

3.2.6.7 Harvesting

The crop was harvested when the inner portion of shell turned brown and kernels turned pink in color indicating its maturity. In each sub-plot, an area of 3.3 x 6 m was first marked with color ribbons, and then all plants in the marked area were harvested and pod and haulm fresh weights recorded. A sub-sample of 0.5 kg pod and 1 kg haulm from each treatment was brought to laboratory and air-dried weights were recorded. Dry yields were then estimated based on the moisture contents in fresh haulm and pod yields.

3.2.7 Data collection

3.2.7.1 Plant growth

Plant growth was measured at 60 and 90 days after sowing (DAS), and at final harvest. Data on plant height, leaf area, dry matter production, and pod number were measured on five plants randomly selected from each treatment plot. Plants were uprooted carefully along with pods, washed with tap water, and individual plants were separated into components parts (leaves, stem, root, pods).

3.2.7.1.1 Plant height

Plant height (cm plant ^{1}) was measured from tip to base of the stem.

3.2.7.1.2 Leaf area

Leaf area (cm^2 plant^{-1}) was measured by using an automatic area meter (Model LI 3100 Licor).

3.2.7.1.3 Dry matter production

Individual plant parts were oven dried at 60°C for three days, and respective dry weights (g plant^{-1}) were recorded.

3.2.7.1.4 Pod number

Total pod number plant^{-1} was recorded at each growth sampling.

3.2.7.1.5 Visual chlorosis symptoms

The severity of chlorosis was measured by a visual chlorotic rating (VCR) system on a 1-5 scale as suggested by Potdar and Anders (1992). The details of VCR system are given below:

1. 0 % chlorosis, highly resistant.
2. 1 - 25 % chlorosis, moderately resistant.
3. 26 - 50 % chlorosis, moderately susceptible.
4. 51 - 75 % chlorosis, susceptible.
5. 76 - 100 % chlorosis, highly susceptible.

3.2.7.2 Yield and yield attributes

3.2.7.2.1 Haulm and pod yields

Dry haulm and pod yields (kg ha^{-1}) were estimated from data on their respective fresh weights (kg net plot^{-1}) and moisture contents.

3.2.7.2.2 Harvest Index

Harvest index (%) was expressed as the % ratio of dry pod yield to total biological yield.

3.2.7.2.3 Test weight and shelling turn over

After pod shelling, 100 seeds were randomly selected from each treatment and their respective weights were recorded (g 100 seeds^{-1}). Shelling turnover was calculated as a % ratio of kernel weight to pod weight.

3.2.8 Plant chemical analysis

3.2.8.1 Estimation of leaf chlorophyll and extractable Fe contents

The first fully opened leaf samples (~200 g) were collected in an airtight polythene bags stored in an ice box and brought to the laboratory for analysis. Leaves were copiously washed with tap water, followed by 0.1N HCl and distilled water. The samples were freed off the sticking water drops by sandwitching them between the sheets of blotting papers. Leaves were then cut into small pieces of approximately 1-2 mm with the help of stainless steel scissors and further chemical analysis was done.

O-phenanthroline extractable iron (ppm) was determined by the method described by Katyal and Sharma (1980).

Leaf chlorophyll content (mg g^{-1} fresh wt.) was determined by using the method described by Hiscox and Israelstam (1978).

3.2.8.2 Estimation of nutrient contents in plant parts

Oven dried plant samples (leaves, stem) collected at 90 DAS were finely ground using a Willey mill with stainless steel blades and passed through a 0.5 mm mesh sieve and used for chemical analysis.

Plant samples were analyzed colorimetrically for nitrogen and phosphorus following digestion on a block digester using a Technicon Autoanalyzer II (Technicon (1972). Total calcium, magnesium, potassium, iron, zinc, copper and manganese contents were estimated by atomic absorption spectrophotometer following digestion of plant samples using the tri-acid digestion method (Jackson, 1967).

3.2.8.2.1 Nutrient uptake

The uptake of various nutrients by leaves and stems of groundnut was calculated by multiplying concentration of each nutrient and dry weights (plant^{-1}) of respective plant parts.

3.2.8.3 Estimation and oil and protein content

3.2.8.3.1 Oil content

Oil content (%) in groundnut kernels was estimated by using a Nuclear Magnetic Resonance (NMR) procedure suggested by Jambunathan *et al.*, (1985).

3.2.8.3.2 Protein content

Protein content (%) in groundnut kernels was estimated by using the method as prescribed by Singh and Jambunathan, (1980).

3.2.9 Economic analysis

The total cost of cultivation ha^{-1} for groundnut production was estimated for individual treatments based on the total labour and inputs used and prevailing market prices.

Gross monetary returns were calculated based on yields obtained and the prevailing market prices for pod and haulm. Net monetary returns were calculated by deducting the cost of cultivation from the gross monetary returns.

Benefit/Cost ratio was calculated as a ratio of net returns and total cost of cultivation.

3.2.10 Data analysis

The experimental data were analyzed statistically by a standard analysis of variance (ANOVA) technique using a Genstat Statistical Package available at the Computer Services at ICRISAT. Statistical significance of treatment effects were evaluated by following the " F test" at $P < 0.05$ and 0.01 levels. Standard error (SE) and critical difference (CD) were calculated and used for comparing treatment means.

RESULTS

CHAPTER IV

RESULTS

The results of the village surveys and statistically analyzed data pertaining to the on-farm trial are presented in this chapter.

4.1 Village surveys

4.1.1 Groundnut production practices

4.1.1.1 Cropping systems

Groundnut crop finds a key position in different cropping systems prevalent in Kottapeta and Pasupalla villages in Kurnool district of Andhra Pradesh. In these villages, groundnut is predominantly grown as a sole crop and intercropped with pigeonpea to some extent. It is grown either in rainy season or postrainy season under irrigated conditions.

In Kottapeta, groundnut is mostly grown in rainy season, whereas in Pasupalla it is grown in postrainy season. Rainy season crop is sown in the first week of June, while the postrainy season crop in the last week of December.

In Kottapeta, the predominant cropping systems involving groundnut are: sole groundnut (kharif, K) - irrigated paddy (rabi, R); sole groundnut (K) - sole groundnut (R); sole groundnut (K) - sorghum (R); and groundnut/pigeonpea intercropping. In Pasupalla, irrigated paddy (K) - groundnut (R); cotton (K) - groundnut (R); sunflower (K) - groundnut (R); and groundnut/pigeonpea intercropping are the major cropping systems with groundnut.

4.1.1.2 Soil resources

Most of the farmers (>80%) in the two villages surveyed preferred Vertisols for groundnut production (Fig. 3). In Kottapeta, all the large (100%), and most (90%) small farmers preferred Vertisols to other soils. Whereas, medium farmers equally preferred Vertisols and mixed soils (Fig. 3a). In Pasupalla, all the farmer groups showed strong preferences (>80%) for Vertisols than other soil types (Fig. 3b).

Farmers in both the villages preferred medium to high fertility compared to low fertility soils (Fig. 4). In Kottapeta, all the three farmer groups preferred high fertility, than medium fertility soils (Fig. 4a). Whereas in Pasupalla, soil fertility preference among the farmer groups varied considerably. The majority of small farmers (80%) preferred medium fertility soils, while the large farmers (80%) preferred high fertility soils. Medium farmers had equal preferences for medium and high fertility soils (Fig. 4b).

Farmers in these villages tend to grow groundnut on deep soils than the shallow soils (Fig. 5). In Kottapeta, all small farmers (100%), and most medium (60%) and large farmers (80%) preferred deep soils than the shallow soils (Fig. 5a). In Pasupalla, all the farmer groups showed strong preferences for deep soils (Fig. 5b).

4.1.1.3 Water resources

Bore wells are the major source of irrigation in these villages. Most farmers (>70%) in these villages grow groundnut under irrigation (Fig. 6a and b). In Kottapeta, all the large farmers (100%), majority of medium (80%) and small farmers (60%) grow groundnut under irrigation (Fig. 6a). Similar irrigation practice was followed in Pasupalla (Fig. 6b).

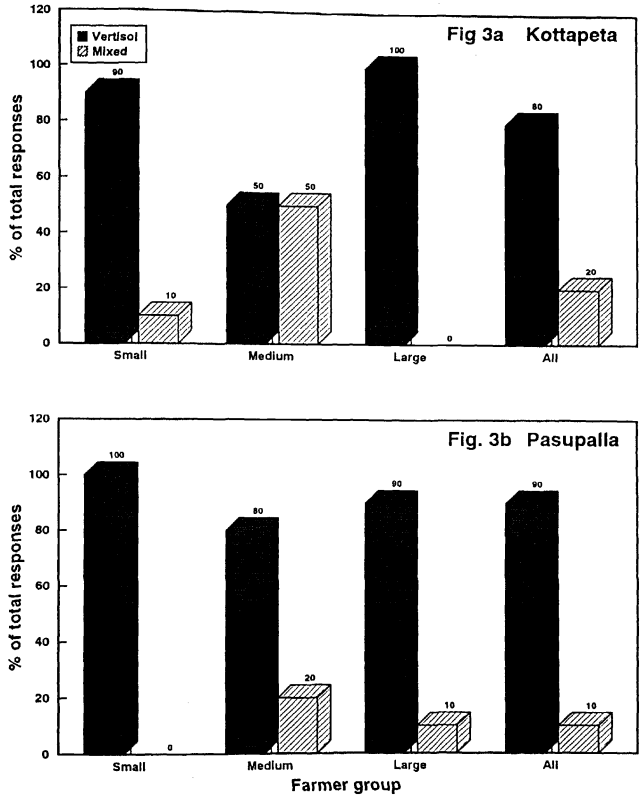


Figure 3. Soil type preferences (%) for groundnut production by sample farmers in Kottapeta and Pasupalla in Kurnool district of Andhra Pradesh, 1992-93.

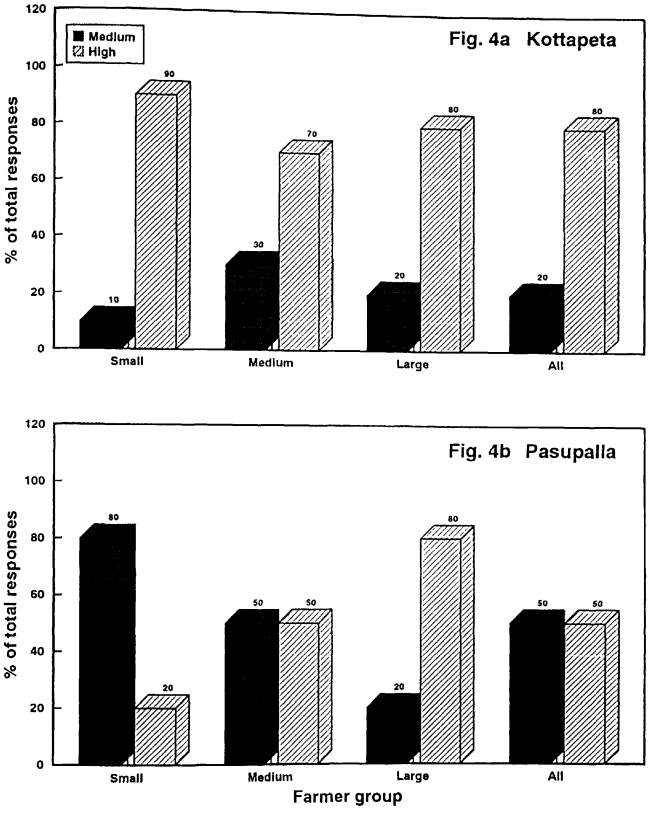
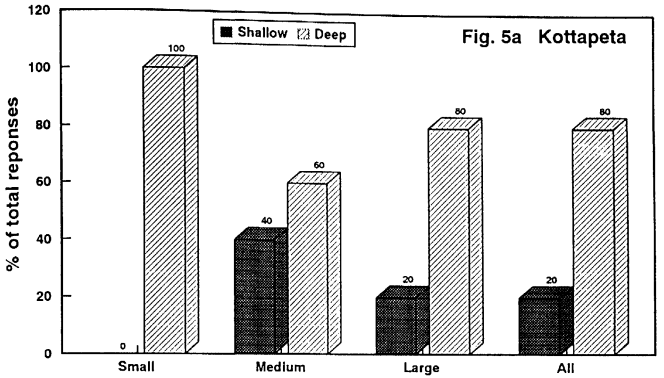


Figure 4. Soil fertility preferences (%) for groundnut production by sample farmers in Kottapeta and Pasupalla in Kurnool district of Andhra Pradesh, 1992-93.



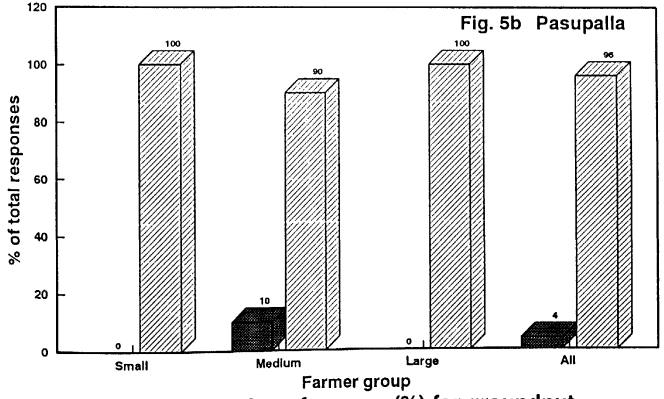


Figure 5. Soil depth preferences (%) for groundnut production by sample farmers in Kottapeta and Pasupalla in Kurnool district of Andhra Pradesh, 1992-93.

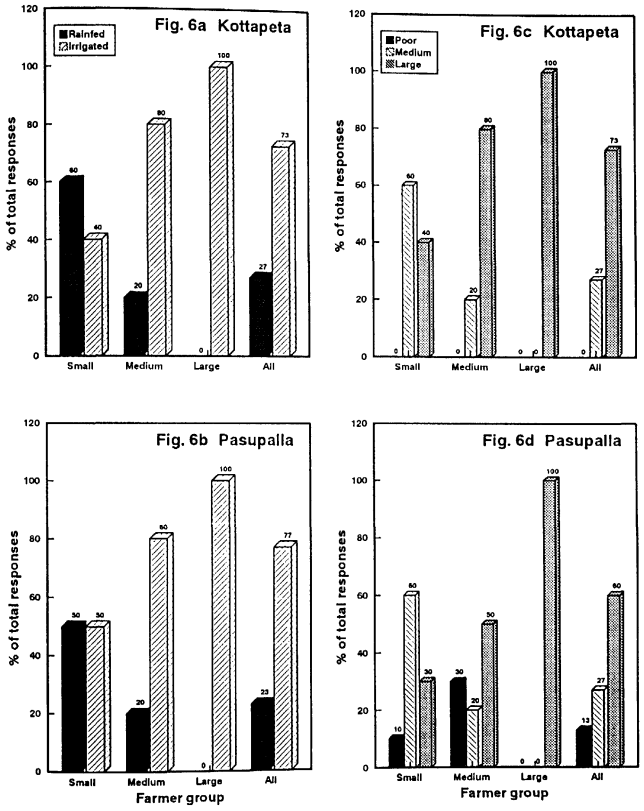


Figure 6. Irrigation practices and quality of irrigation water for groundnut production by sample farmers in Kottapeta and Pasupalla in Kurnool district of Andhra Pradesh, 1992-93.

Farmers rated quality of irrigation water into three categories i.e., good (sweet), medium, and poor (salty). Irrigation water in both the villages was mostly good (>60%) (Fig. 6c and d). In Kottapeta, the quality of irrigation water was mostly good (73%) to medium (27%). Whereas in Pasupalla, it varied from good (60%) to poor (13%). All the large farmers in these villages had good quality water and medium and small farmers had good to poor quality irrigation water.

4.1.1.4 Groundnut genotypes

Local genotype (cv. TMV 2) is predominantly (>85%) grown in both the villages (Fig. 7a and b). All the small farmers grow only TMV 2, whereas medium and large farmers recently began to grow improved genotypes to a small extent (10-20%). These farmers grow some improved genotypes viz., ICGS 11, 44, TPT 1, and JL 24.

4.1.1.5 Sources of seed and sowing practices

Local market, seed from own field and other farmers were the primary sources of groundnut seed used in these villages (Fig. 7c and d). Local market for large farmers, local market or own seed for medium farmers, and other farmers for small farmers were the main sources for obtaining groundnut seeds.

Sowing is generally done by a 4-row seeddrill (Gorru) at a row spacing of 30-cm followed by seed covering with a wooden plank. Seed rate varied from 150 to 200 kg ha^{-1} which is about twice the recommended rate. Seeds are generally not treated with any fungicides or rhizobial culture.

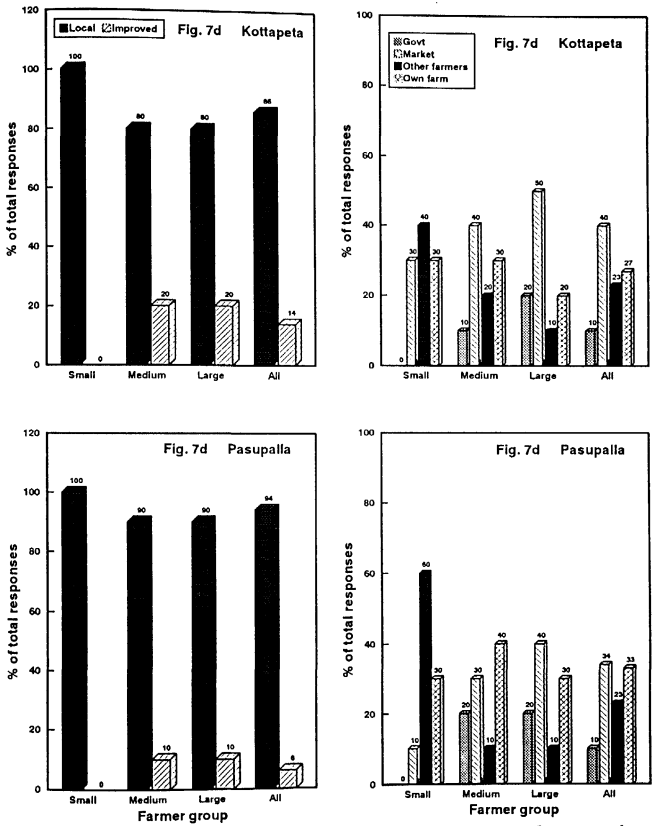


Figure 7. Groundnut genotypes and sources of groundnut seed for sample farmers in Kottapeta and Pasupalla in Kurnool district of Andhra Pradesh, 1992-93.

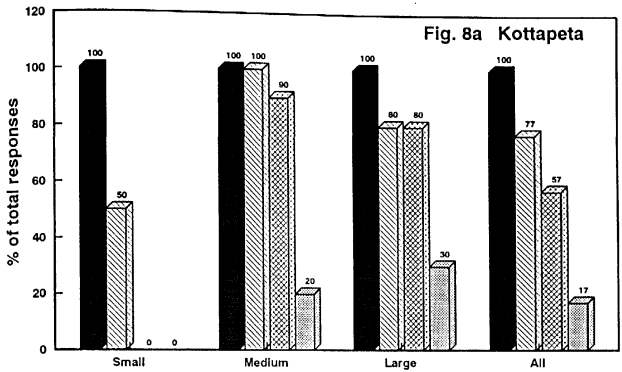
4.1.1.5 Fertilizer management

Farmers in these villages generally apply very high doses of different fertilizers to groundnut. Fertilizers are commonly applied in four split doses (basal + top dressings) in these villages (Fig. 8). The common fertilizers used were Urea, Single super phosphate, Diammonium phosphate (18:46:0), Ammonium phosphate (28:28:0), Gromor (17:17:17), and Calcium ammonium nitrate. Most of the farmers apply a basal fertilizer dose (>90%) followed by one top dressing (>70%), and some farmers (20-60%) even apply an additional one or two top dressings (Fig. 8a and b). Large and medium farmers generally apply fertilizers in four split doses. Whereas, majority (>80%) of the small farmers apply only a basal fertilizer dose. Some farmers (30-50%) apply an additional one top dressing of fertilizers.

Fertilizers are mostly broadcasted rather than drilling (Fig. 9a and b). Fertilizer application methods did not vary among the farmer groups.

4.1.1.6 Quantity of nitrogen applied

Among major nutrients, farmers in these villages tend to apply large quantities of nitrogen (50-250 kg N ha^{-1}) (Fig. 10) and phosphorus (50-350 kg P_2O_5 ha^{-1}) to groundnut. In Kottapeta, 40% of the farmers apply 100-200 kg N ha^{-1}, 26% apply 200-250 kg N ha^{-1}, 24% apply 50-100 kg N ha^{-1}, and 10% do not apply any fertilizers (Fig. 10a). Nitrogen fertilizer application practice in Pasupalla was similar to Kottapeta, except that majority of the farmers (53%) apply high nitrogen doses (200-250 kg N ha^{-1}) (Fig. 10b). Whereas, majority of small farmers apply medium fertilizer dose (50-100 kg N ha^{-1}). Nitrogen



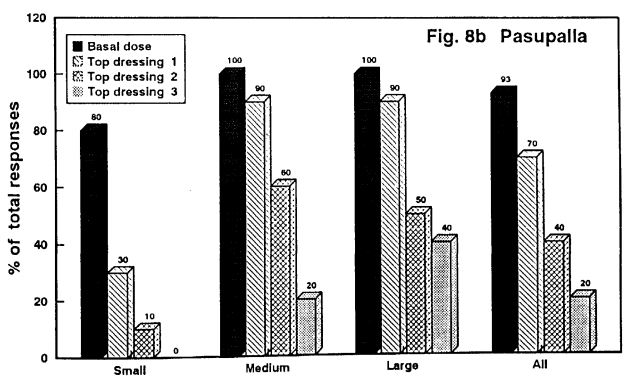


Figure 8. Fertilizer schedule adopted for groundnut production by sample farmers in Kottapeta and Pasupalla in Kurnool district of Andhra Pradesh, 1992-93.

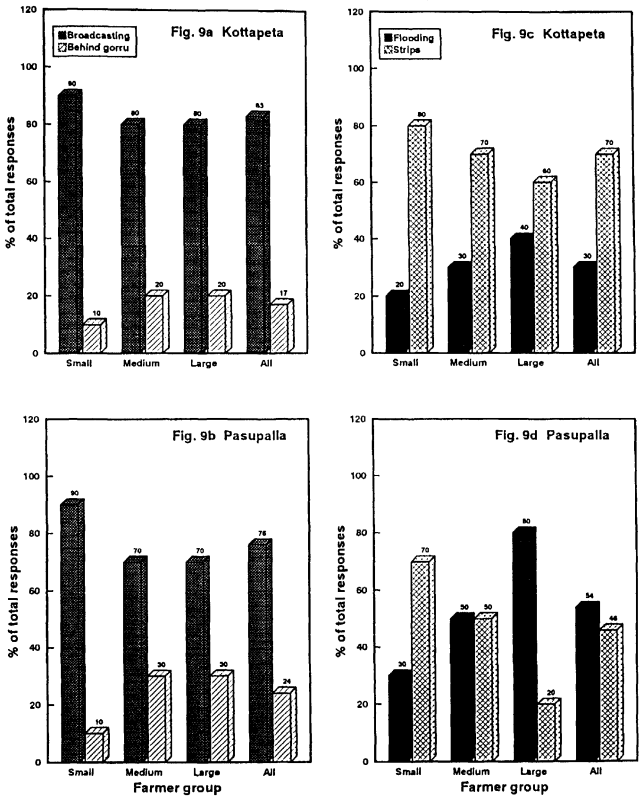


Figure 9. Fertilizer and irrigation practices for groundnut production by sample farmers in Kottapeta and Pasupalla in Kurnool district of Andhra Pradesh, 1992-93.

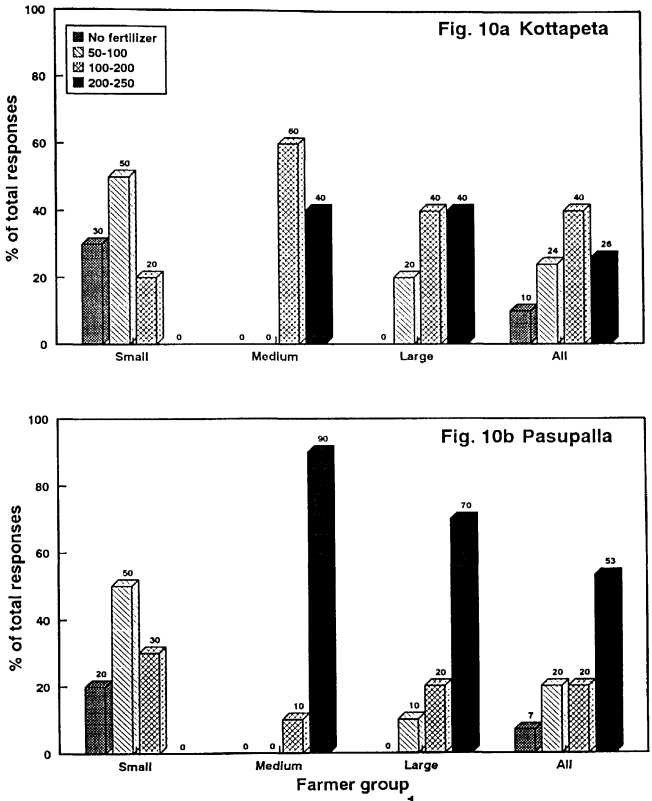


Figure 10. Quantity of nitrogen (kg ha^{-1}) applied for groundnut production by sample farmers in Kottapeta and Pasupalla in Kurnool district of Andhra Pradesh, 1992-93.

application practice among large and medium farmers did not vary in the respective villages. In general, high N doses were applied in Pasupalla than Kottapeta.

4.1.1.7 Irrigation management

Farmers generally irrigate groundnut by flooding or strip irrigation methods (Fig. 9c and d). Groundnut was predominantly irrigated by strip irrigation (70%) in Kottapeta, whereas both the irrigation methods were equally followed in Pasupalla. In Kottapeta, all the groups followed similar irrigation methods. In Pasupalla, large farmer preferred flooding, while small farmers preferred strip irrigation method. Medium farmers showed an equal preference to flooding and strip irrigation methods.

4.1.1.8 Plant protection

Indiscriminate pesticide use is a common practice in these villages. Groundnut is generally sprayed with locally available pesticide starting from 3 to 4 weeks after sowing, and thereafter regularly at 2-weeks interval irrespective of pest incidence. Fungicides are generally not applied to groundnut in these villages.

4.1.2 Production constraints

Farmers were asked to list out the major constraints to groundnut production. Following were the major production constraints identified by the respondents in these villages:

1. Non availability of good quality seed.
2. Early and mid season drought conditions.
3. Severe pest attack by leaf weber, aphids, jassids, and rootgrub.
4. Incidence of rust, and early and late leaf spot.
5. Severe iron chlorosis.

4.1.3 Farmers perceptions of Fe chlorosis

Iron chlorosis is locally known as "**Shanku Tegulu**" meaning a yellow-white disease. Farmers perceptions about Fe chlorosis, severity of the problem, causes and management practices for Fe chlorosis, and associated yield losses in groundnut are briefly summarized below.

4.1.3.1 Occurrence, distribution and severity of Fe chlorosis

Farmers described Fe chlorosis as a major constraint to groundnut production in these villages (Fig. 11). The problem was more widespread in Pasupalla (77%) (Fig. 11a) than Kottapeta (60%) (Fig. 11b). However, the problem appears to be more severe with the medium farmers than small and large farmers.

When asked about the nature of distribution (patchy or uniform) of Fe chlorosis in their groundnut fields. Farmers reported that Fe chlorosis can occur as patches or uniform chlorosis of entire field (Fig. 11c and d). In Kottapeta, Fe chlorosis mostly occurred in patches, and in Pasupalla it occurred both as patches and uniform chlorosis of entire field. Fe chlorosis mainly occurred in patches with small farmers.

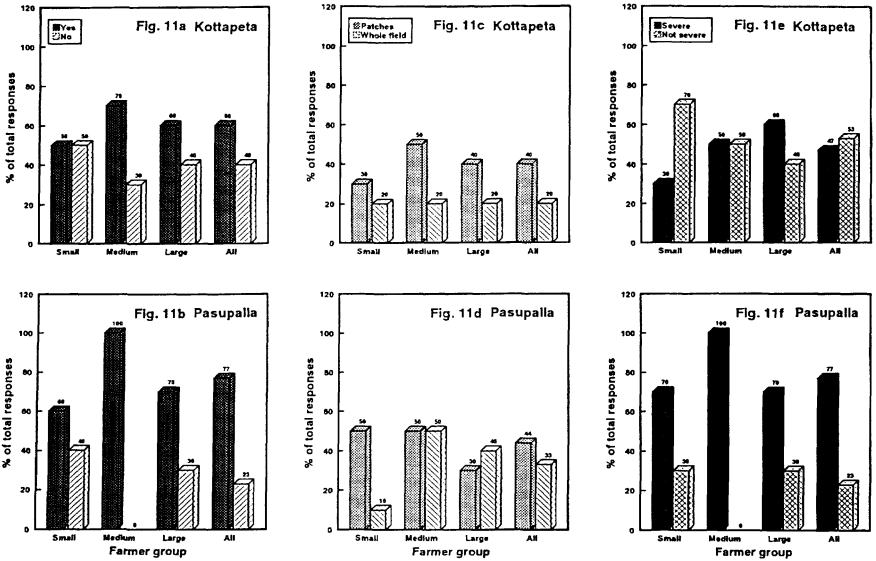


Figure 11. Occurence, distribution and severity of iron chlorosis in groundnut grown by sample farmers in Kottapeta and Pasupalla in Kurnool district of Andhra Pradesh, 1992-93.

Fe chlorosis in groundnut is a common problem in these villages (Fig. 11e and f). However, the problem was more severe in Pasupalla than Kottapeta. In Kottapeta, the problem was more severe with large farmers than small farmers. Whereas in Pasupalla, all the farmer groups reported severe Fe chlorosis.

4.1.3.2 Yield losses due to Fe chlorosis

The average groundnut pod yields in these villages varied from 1.5 to 2 t ha^{-1} (Fig. 12a and b). Higher pod yields were obtained in Pasupalla than Kottapeta. Medium and large farmers reported higher pod yields than the small farmers.

Severe yield losses (20-40%) due to Fe chlorosis were reported by all the farmer groups in both the villages (Fig. 12c and d). However, the yield losses were more (35-40%) in Pasupalla than in Kottapeta (20-28%). Yield losses did not vary among the farmer groups.

4.1.3.3 Causes of Fe chlorosis

When questioned about the main factors causing Fe chlorosis, farmers identified several factors related to soil, climate, genotype, irrigation and fertilizer practices responsible for Fe chlorosis in groundnut (Fig. 13). Farmers in both of these villages perceived low soil fertility, high lime content in soil, high soil alkalinity, excess irrigation and waterlogging, and nitrogen deficiency as the main factors for Fe chlorosis.

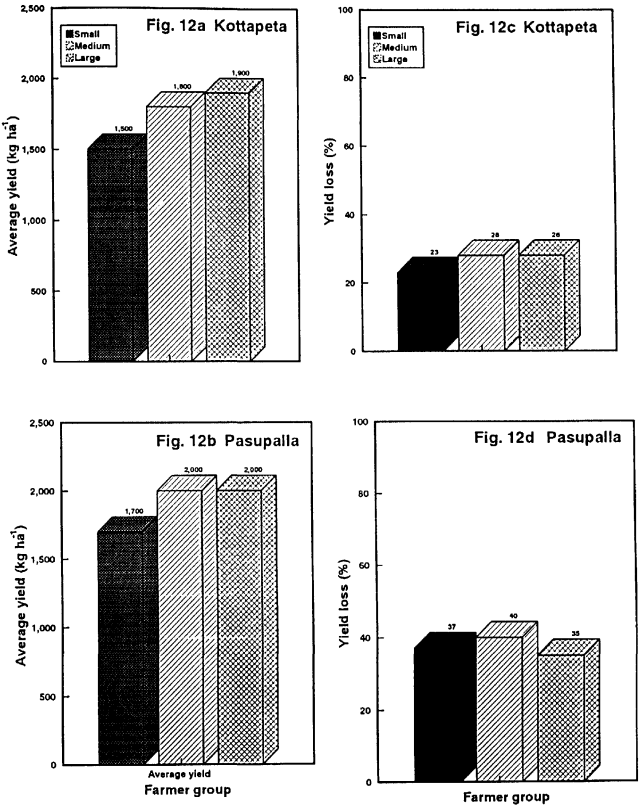


Figure 12. Average yields and yield losses due to Fe chlorosis in groundnut grown by sample farmers in Kottapeta and Pasupalla in Kurnool district of Andhra Pradesh, 1992-93.

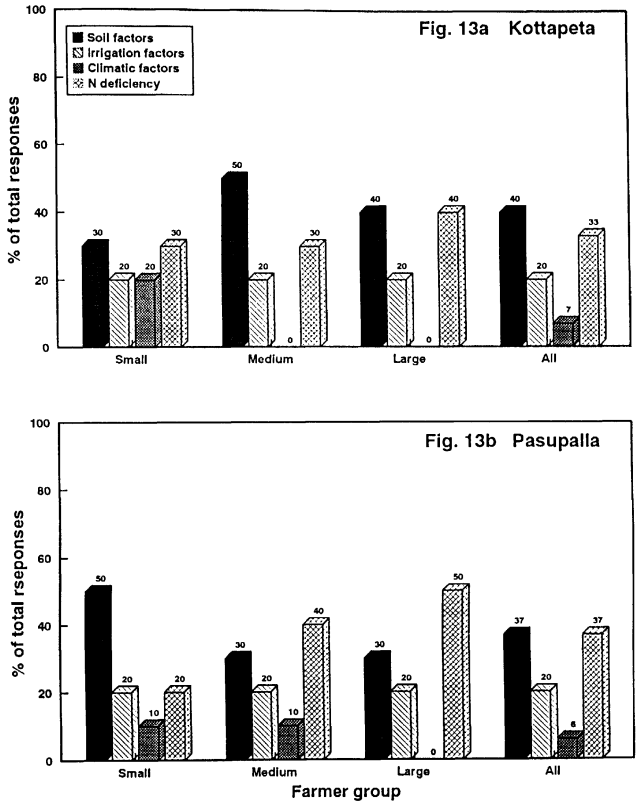


Figure 13. Perceptions of the causal factors for iron chlorosis in groundnut by sample farmers in Kottapeta and Pasupalla in Kurnool district of Andhra Pradesh, 1992-93.

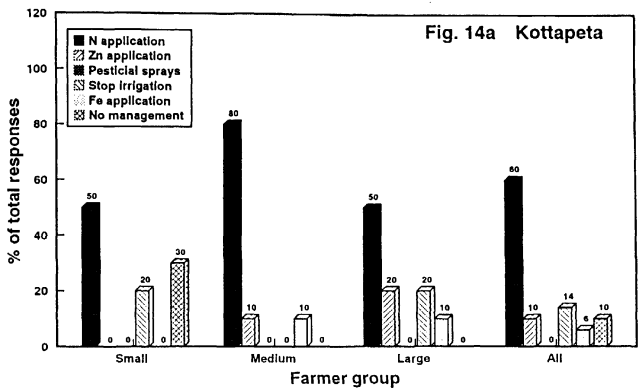
In Kottapeta farmer perceptions about causal factors for Fe chlorosis did not vary among the farmer groups (Fig. 13a). Whereas in Pasupalla, nitrogen deficiency by large and medium farmers, and soil factors by the small farmers were considered as main factors causing Fe chlorosis (Fig 13b). Among the climatic factors, high rainfall and low sunshine were considered as the additional factors for Fe chlorosis.

4.1.3.4 Management of Fe chlorosis

Farmers adopted different management practices for alleviation of Fe chlorosis in groundnut, which included practices such as use of nitrogen, zinc, iron and pesticides, and delay in irrigation (Fig. 14). However, application of nitrogenous fertilizers was the most common management strategy adopted by the farmers in these villages (Fig. 14a and b). Large and small farmers generally adopted different management practices, whereas most small farmers apply only nitrogen fertilizer or do not adopt any management practice for Fe chlorosis in groundnut.

4.1.4 Future management practices

Despite of the Fe chlorosis problem, most farmers in these villages were interested to continue groundnut production due to its high economic and fodder value. Some farmers, for with severe Fe chlorosis wanted to replace groundnut by sunflower which in their opinion is considered as Fe-efficient crop. Some farmers were convinced with the use of $FeSO_4$ sprays for correction of Fe chlorosis.



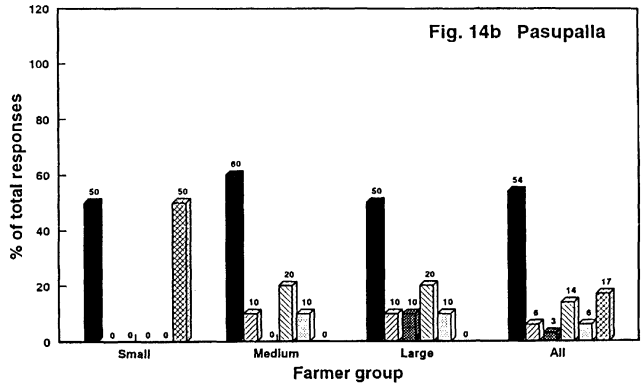


Figure 14. Management practices adopted for iron chlorosis in groundnut by sample farmers in Kottapeta and Pasupalla in Kurnool district of Andhra Pradesh, 1992-93.

Figure 15a. Severe iron chlorosis in groundnut in farmer's field (top) and experimental plots at RARS (bottom), Nandyal in Andhra Pradesh, 1992-93.

4.2 On farm experiment

4.2.1 Diagnosis of Fe chlorosis

4.2.1.1 Visual deficiency symptoms

Fe chlorosis symptoms appeared on young leaves within 20 DAS (Fig. 15b), characterized by initial interveinal chlorosis on young leaves with veins remained green, and later on vanished and finally whole leaf including petiole became yellow. Severe and uniform Fe chlorosis symptoms were noticed in Fe inefficient genotypes (TMV 2 and ICGS 11, Fig. 15c).

4.2.1.1.1 Severity of Fe chlorosis

Severity of Fe chlorosis was rated by a **"visual chlorosis rating" (VCR)** scale (1 to 5) on the basis of severity of chlorosis and extent of plot area affected. VCR was recorded at 40, 60, 90 DAS and at final harvest. Mean VCR values varied significantly among different genotypes at all growth stages (Fig. 16a). Moderate chlorosis (VCR = > 2) was observed in TMV 2 and ICGS 11, whereas ICGV 86031 remained green throughout growth from seedling to final harvest.

Different fertilizer practices had no significant influence on mean VCR values at all the growth stages (Fig. 16b). Foliar Fe sprays significantly reduced mean VCR to the extent of 29, 37 and 28% at 60, 90 DAS and at final harvest respectively over the nonsprayed control (Fig. 16c).

Genotype x Fe sprays interaction was significant at 60, 90 DAS and at final harvest where TMV 2 and ICGS 11 with foliar Fe sprays resulted in significantly lower

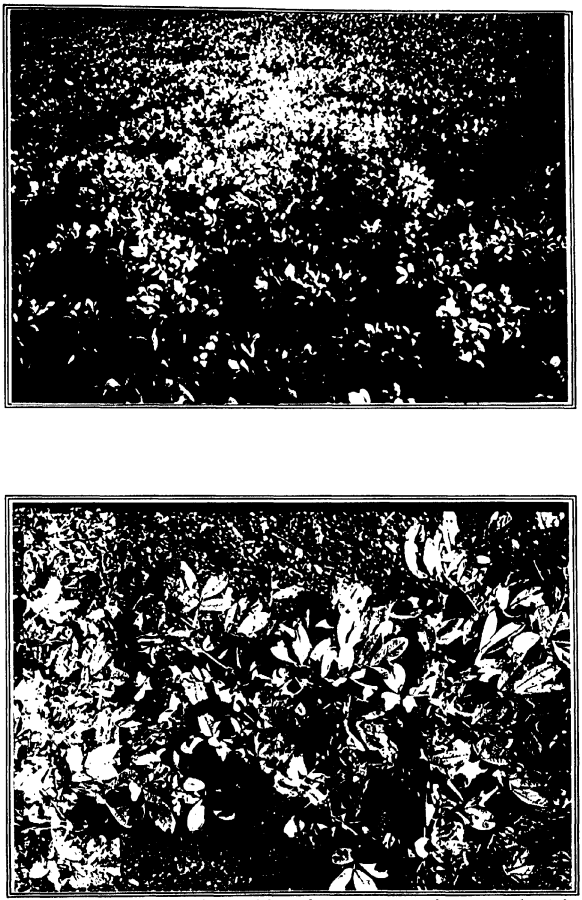


Figure 15b. Typical iron chlorotic symptoms in groundnut in farmer's field in Kottapeta (top) and Pasupalla (bottom) villages in Andhra Pradesh, 1992-93.

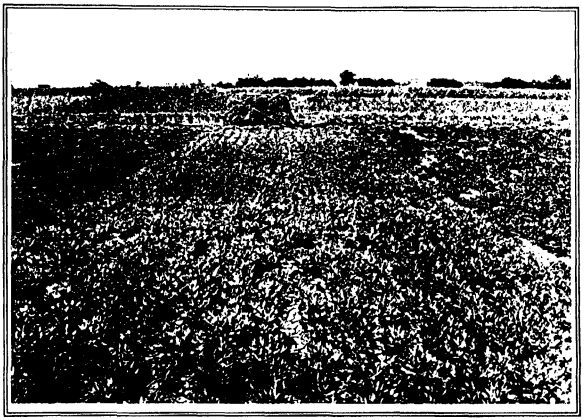
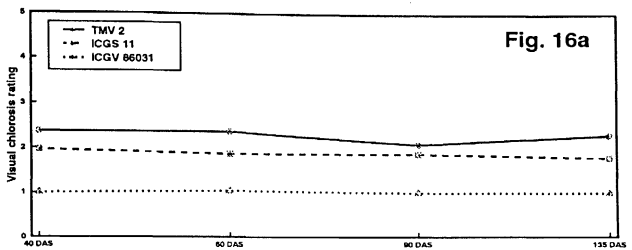
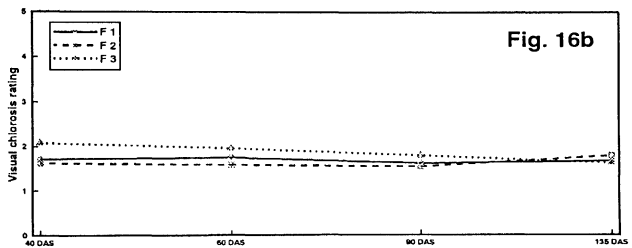
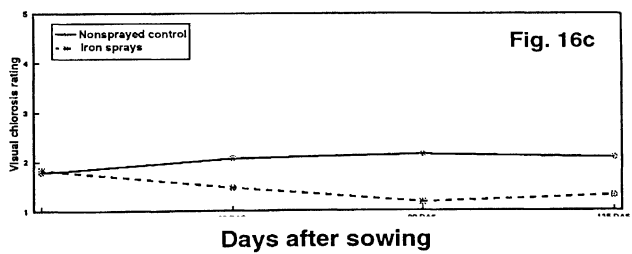


Figure 15c. Experimental groundnut field showing moderate chlorosis in ICGS 11 (left) and TMV 2 (middle), and no chlorosis in ICGV 86031 (right) at Kottapeta village in Kurnool district of Andhra Pradesh, 1992-93.







Days after sowing

Figure 16. Mean visual chlorosis rating (VCR) values of groundnut genotypes under different fertilizer practices and foliar iron sprays at 40, 60, 90 DAS and at final harvest.

mean VCR values. Fertilizer x genotype interaction was significant only at final harvest (Fig. 17), where TMV 2 under farmer fertilizer practice recorded the maximum VCR value (2.62). Mean VCR values were significantly reduced by foliar Fe sprays.

A trend in overall mean VCR (n=4) values under different treatments (Table 6) was similar to individual VCR values measured at 60, 90, DAS and at final harvest. However, the overall mean VCR was significantly affected by different interactions between treatment (G x Fe and F x G x Fe), where ICGV 86031 under sprayed and nonsprayed conditions or ICGS 11 under sprayed condition recorded the lowest overall mean VCR values (Fig. 18). Similarly, ICGS 11 grown under farmer fertilizer practice with no Fe sprays recorded the highest overall mean VCR value of 3.1 (Fig. 19), whereas the lowest overall mean VCR values were observed in ICGS 11 grown under no fertilizer or recommended fertilizer practices with Fe sprays. In contrast, ICGV 86031 remained green under all fertilizer practices and Fe spray treatments (VCR = 1).

4.2.1.2 Chemical analysis

4.2.1.2.1 Total Fe content in leaves (ppm)

Total Fe content in leaves of groundnut genotypes did not vary significantly at 90 DAS (Table 6). However, total Fe content in leaves of TMV 2 was generally higher than ICGS 11 and ICGV 86031.

Similarly, there was no significant effect of different fertilizer practices on total Fe content in groundnut leaves. However, recommended fertilizer practice resulted in higher total Fe content than farmers fertilizer practice and no fertilizer control.

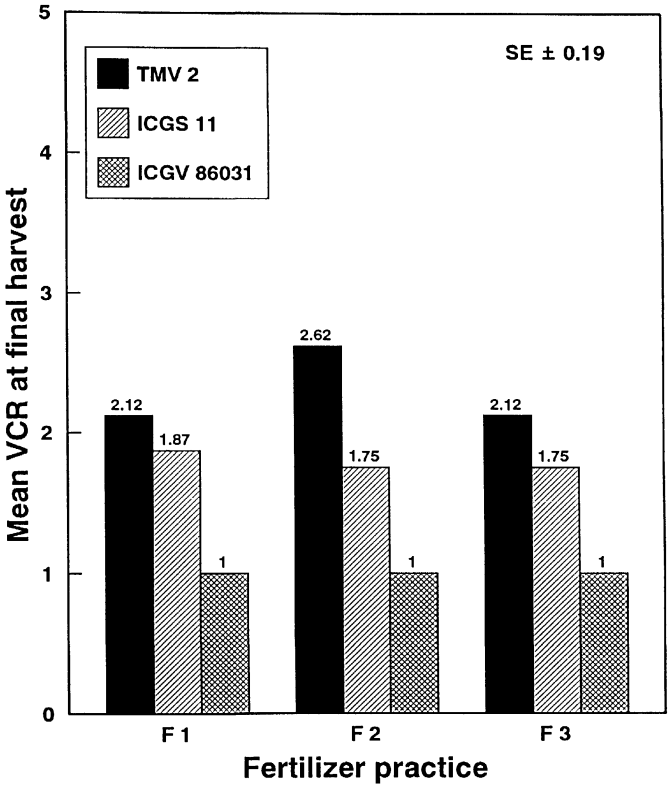


Figure 17. Interaction between fertilizer practices and genotypes on mean visual chlorosis rating (VCR) values of groundnut.

Table 6. Mean chlorophyll content (mg g^{-1} fresh wt.), extractable and total iron (ppm), and overall mean visual chlorosis rating in leaves of groundnut genotypes under different fertilizer practices and foliar iron sprays at 90 days after sowing.

Treatment	Chlorophyll	Extractable Fe	Total Fe	overall mean VCR
Genotypes (G)				
TMV 2	5.21	30.10	254.00	2.28
ICGS 11	5.61	32.30	219.00	1.87
ICGV 86031	6.81	35.30	200.00	1.01
SE ±	0.17	3.54	20.30	0.10
CD	0.89**	NS	NS	0.44**
Fertilizer practices (F)				
No fertilizer	6.04	34.00	219.00	1.69
Farmer practice	5.74	31.70	212.00	1.63
Recommended practice	5.85	32.30	243.00	1.86
SE ±	0.161	1.32	7.10	0.20
CD	NS	NS	NS	NS
Iron sprays (Fe)				
Nonsprayed control	5.01	9.70	79.00	2.01
Fe sprays	6.75	55.60	370.00	1.44
SE ±	0.167	3.42	19.00	0.08
CD	0.654**	13.40**	74.44**	0.31**
Interactions SE ±				
F x G	0.30	4.23	26.00	0.24
F x Fe	0.26	4.40	24.30	0.22
G x Fe	0.27**	5.49	30.90	0.14**
F x G x Fe	0.47	8.41	48.00	0.29*

*,** = Significant at $P < 0.05$ and 0.01 level, respectively.

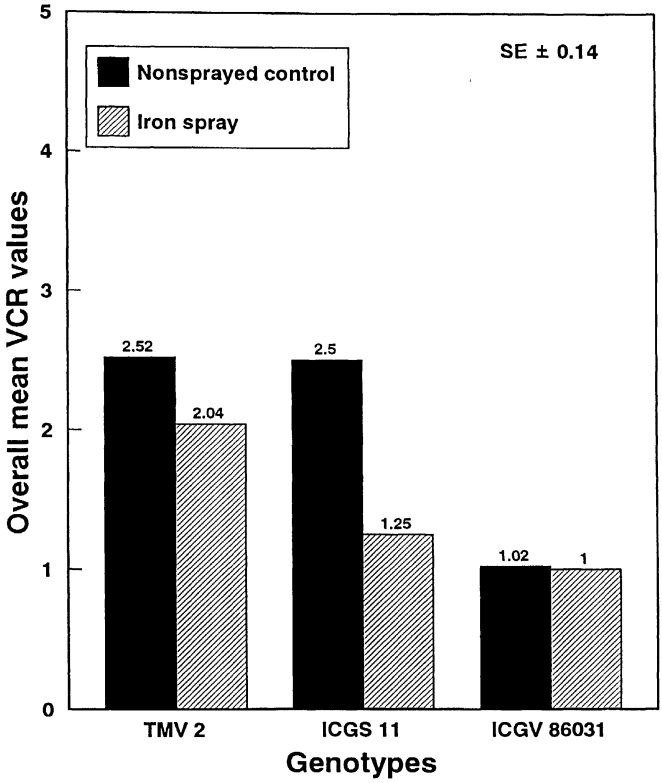


Figure 18. Interaction between genotypes and foliar Fe sprays on the over-all mean visual chlorosis rating (VCR) values of groundnut.

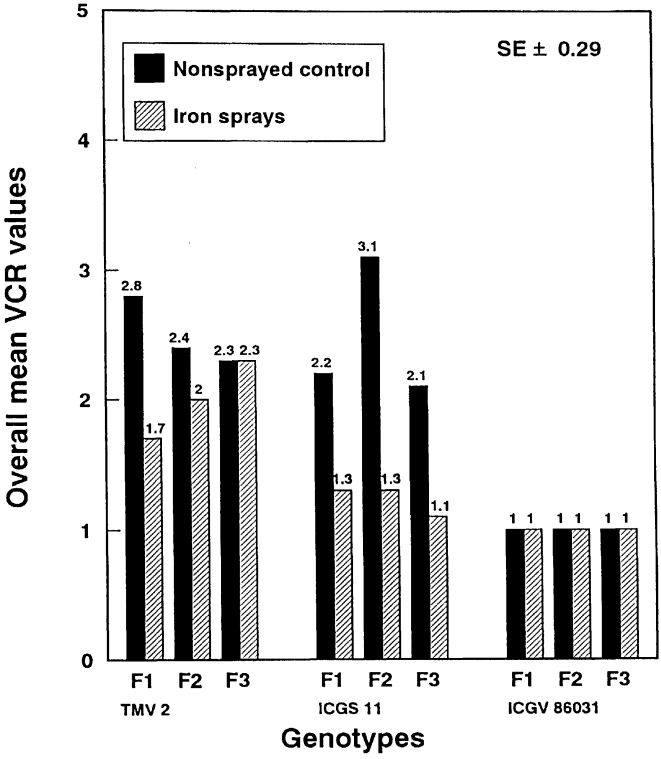


Figure 19. Interaction between fertilizer practices, genotypes, and foliar Fe sprays on the mean visual chlorosis rating (VCR) values of groundnut.

Foliar Fe sprays significantly increased total Fe content in groundnut leaves by 368% over the nonsprayed control (79 ppm). Interactions between treatments were nonsignificant.

4.2.1.2.2 Extractable Fe content in leaves (ppm)

Extractable Fe content in leaves of groundnut genotypes did not vary significantly (Table 6). However, extractable Fe content in ICGV 86031 (35.3 ppm) was relatively higher than in ICGS 11 (32.2 ppm) and TMV 2 (30.10 ppm). Similarly, there was no significant effect of different fertilizer practices on extractable Fe content in groundnut leaves.

Foliar Fe sprays significantly increased extractable Fe content in groundnut leaves by 473% over the nonsprayed control (9.7 ppm). Interactions between treatments were nonsignificant.

4.2.1.2.3 Chlorophyll content in leaves (mg g^{-1}, fresh wt.)

Leaf chlorophyll content in groundnut genotypes varied significantly at 90 DAS (Table 6). ICGV 86031 recorded significantly more leaf chlorophyll content than ICGS 11 and TMV 2. Foliar Fe sprays significantly increased leaf chlorophyll content by 34.7% over the nonsprayed control.

However, different fertilizer practices did not significantly affect the leaf chlorophyll content of groundnut.

Interaction between genotypes and Fe sprays significantly affected the leaf chlorophyll content of groundnut (Fig. 20), where ICGV 86031 with or without foliar Fe sprays contained significantly high chlorophyll values. The lowest chlorophyll content was found in ICGS 11 with no Fe sprays.

4.2.2 Growth parameters

4.2.2.1 Plant height (cm)

Plant height of groundnut genotypes differed significantly at all the growth stages (Table 7). TMV 2 and ICGV 86031 grew significantly taller than ICGS 11 at 60 and 90 DAS. While, the highest plant height was noticed at final harvest in case of ICGV 86031 at final harvest. There was no significant effect of different fertilizer practices on plant height of groundnut at all the growth stages.

Foliar Fe sprays significantly increased plant height of groundnut by 12.5% over nonsprayed control only at 60 DAS. None of the interaction was significant.

4.2.2.2 Leaf area (cm^2 $plant^{-1}$)

Leaf area of groundnut genotypes varied significantly only at 90 DAS and at final harvest (Table 8). ICGV 86031 and ICGS 11 produced significantly more leaf area than TMV 2 at 90 DAS. Whereas, at final harvest ICGV 86031 produced significantly higher leaf area than TMV 2 and ICGS 11. Leaf area was not significantly influenced by different fertilizer practices at all the growth stages.

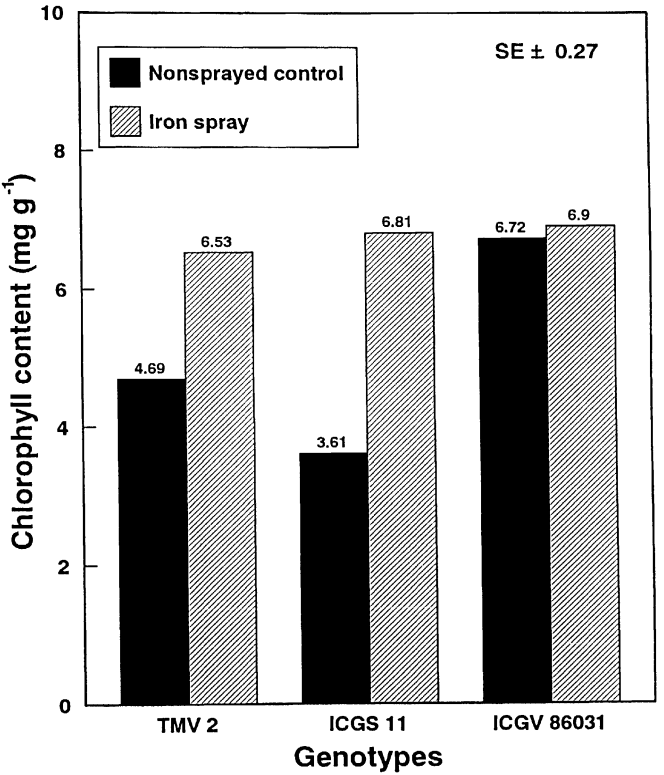


Figure 20. Interaction between genotypes and foliar iron sprays on leaf chlorophyll content (mg g^{-1} fresh wt.) of groundnut at 90 DAS.

Table 7. Mean plant height (cm plant^{-1}) of groundnut genotypes under different fertilizer practices and foliar iron sprays at 60, 90 DAS and at final harvest.

Treatment	Days after sowing		
	60	90	Final harvest
Genotypes (G)			
TMV 2	12.47	26.13	24.91
ICGS 11	10.63	21.09	23.27
ICGV 86031	12.38	23.63	26.94
SE ±	0.41	0.47	0.65
CD	1.82*	2.46**	2.88*
Fertilizer practices (F)			
No fertilizer	11.11	22.77	23.81
Farmer practice	11.76	24.21	26.31
Recommended practice	11.61	23.87	25.00
SE ±	0.33	0.47	0.71
CD	NS	NS	NS
Iron sprays (Fe)			
Nonsprayed control	11.13	23.43	24.86
Fe sprays	12.52	23.81	25.22
SE ±	0.31	0.31	0.40
CD	0.90*	NS	NS
Interactions SE ±			
F x G	0.59	0.85	1.16
F x Fe	0.50	0.60	1.86
G x Fe	0.56	0.61	0.82
F x G x Fe	0.89	1.08	1.44

*,** = Significant at $P < 0.05$ and 0.01 level, respectively.

Table 8. Mean leaf area (cm^2 $plant^{-1}$) of groundnut genotypes under different fertilizer practices and foliar iron sprays at 60, 90 DAS and at final harvest.

Treatment	Days after sowing		
	60	90	Final harvest
Genotypes (G)			
TMV 2	224.5	554.7	554.0
ICGS 11	249.2	632.9	496.0
ICGV 86031	239.1	649.5	754.0
SE ±	8.8	17.5	24.3
CD	NS	77.8*	108.0*
Fertilizer practices (F)			
No fertilizer	209.3	593.3	593.0
Farmer practice	266.2	648.7	610.0
Recommended practice	237.3	594.1	601.0
SE ±	18.6	26.2	13.8
CD	NS	NS	NS
Iron sprays (Fe)			
Nonsprayed control	207.7	571.5	582.0
Fe sprays	267.5	653.3	621.0
SE ±	7.4	11.8	16.8
CD	29.0**	46.2**	NS
Interactions			
SE ±			
F x G	24.7	37.6	33.1
F x Fe	20.7	29.9*	24.7
G x Fe	12.6	22.7	31.8**
F x G x Fe	29.3	45.2	48.7

*,** = Significant at $P < 0.05$ and 0.01 level, respectively.

Foliar Fe sprays significantly increased leaf area by 29% and 14.3% at 60 and 90 DAS, respectively over the nonsprayed control.

Groundnut leaf area was significantly affected by different interactions among treatments at 90 DAS and at final harvest. At 90 DAS, ICGV 86031 grown under recommended fertilizer practice or farmer fertilizer practice caused the maximum leaf area (Fig. 21). While at final harvest, ICGV 86031 with foliar Fe sprays produced the highest leaf area (Fig. 22).

4.2.2.3 Leaf dry weight (g plant^{-1})

Leaf dry weight plant^{-1} of groundnut genotypes differed significantly at all the growth stages (Table 9). ICGV 86031 produced significantly higher leaf dry weights than ICGS 11 and TMV 2 at all the growth stages. The differences in the leaf dry weights due to different fertilizer practices were not significant at various growth stages.

Foliar Fe sprays significantly increased leaf dry weight by 94% and 23% at 60 and 90 DAS, respectively over nonsprayed control.

Interaction of genotypes and Fe sprays significantly affected leaf dry weight of groundnut at final harvest (Fig. 23), ICGV 86031 with foliar Fe sprays resulted in the highest leaf dry weight (8.91). While, the lowest was produced by ICGS 11 with no Fe sprays (3.99).

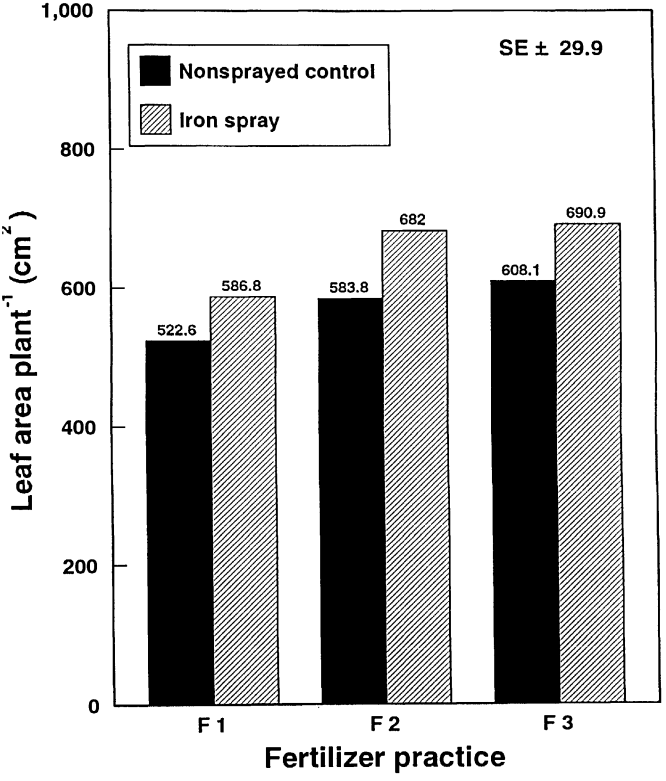


Figure 21. Interaction between fertilizer practices and foliar iron sprays on groundnut leaf area plant^{-1} at 90 DAS.

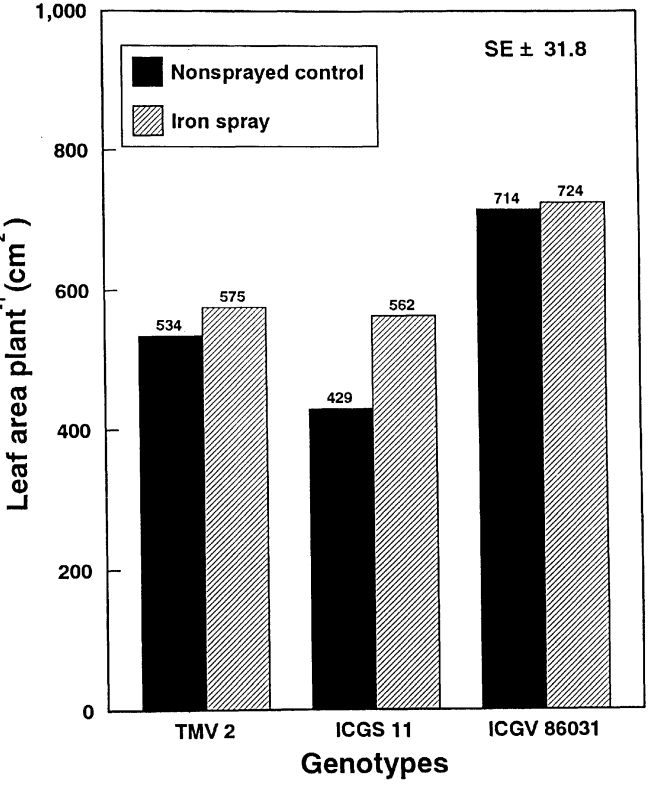


Figure 22. Interaction between genotypes and foliar Fe sprays on groundnut leaf area plant^{-1} at final harvest.

Table 9. Mean leaf dry weight (g plant^{-1}) of groundnut genotypes under different fertilizer practices and foliar iron sprays at 60, 90 DAS and at final harvest.

Treatment	Days after sowing		
	60	90	Final harvest
Genotypes (G)			
TMV 2	1.72	4.09	4.69
ICGS 11	1.94	4.35	4.45
ICGV 86031	2.65	6.35	8.33
SE ±	0.16	0.27	0.36
CD	0.71*	1.41**	1.89**
Fertilizer practices (F)			
No fertilizer	1.92	4.92	5.64
Farmer practice	2.23	5.23	5.89
Recommended practice	2.06	4.64	5.95
SE ±	0.13	0.15	0.20
CD	NS	NS	NS
Iron sprays (Fe)			
Nonsprayed control	1.18	4.17	5.80
Fe sprays	2.29	5.15	5.85
SE ±	0.07	0.14	0.21
CD	0.27**	0.41*	NS
Interactions			
SE ±			
F x G	0.24	0.36	0.48
F x Fe	0.16	0.23	0.33
G x Fe	0.18	0.32	0.45*
F x G x Fe	0.28	0.47	0.66

* = Significant at $P < 0.05$ and 0.01 level, respectively.

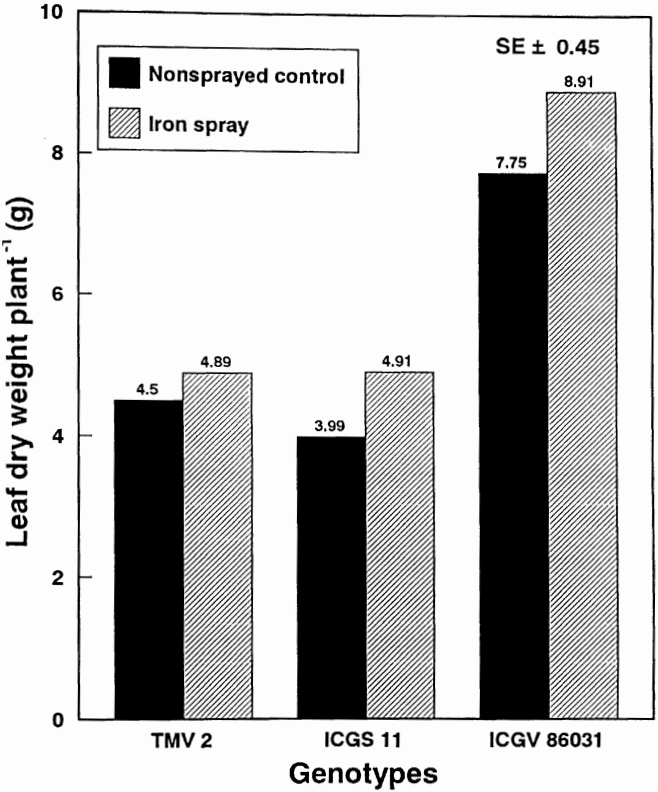


Figure 23. Interaction between genotypes and foliar iron sprays on groundnut leaf dry weight plant^{-1}at final harvest.

4.2.2.4 Stem dry weight (g plant^{-1})

Stem dry weight plant^{-1} of groundnut genotypes varied significantly at only 90 DAS and at final harvest (Table 10). Significantly higher stem dry weight was produced by ICGV 86031 than TMV 2 and ICGS 11 at the above stages of crop growth.

Different fertilizer practices did not exert significant influence on groundnut stem dry weights at all the growth stages. Foliar Fe sprays significantly increased groundnut stem dry weight by 21.5% and 18.3% at 60 and 90 DAS, respectively over nonsprayed control.

The affect of interaction between genotypes and Fe sprays was significant only at final harvest (Fig. 24), ICGV 86031 with or without Fe sprays produced maximum stem dry weights.

4.2.2.5 Root dry weight (g plant^{-1})

The differences in root dry weight plant^{-1} of groundnut genotypes were significant at 90 DAS and at final harvest (Table 11). The genotype ICGV 86031 was significantly superior with root dry weight to TMV 2 and ICGS 11. The root dry weights was not significantly affected by different fertilizer practices at all growth stages.

Foliar Fe sprays significantly increased root dry weights of groundnut by 14.9% and 17.4% at 60 and 90 DAS, respectively over nonsprayed control. None of the interaction between treatments was significant for root dry weights at all the growth stages.

Table 10. Mean stem dry weight (g plant^{-1}) of groundnut genotypes under different fertilizer practices and foliar iron sprays at 60, 90 DAS and at final harvest.

Treatment	Days after sowing		
	60	90	Final harvest
Genotypes (G)			
TMV 2	1.69	4.17	4.60
ICGS 11	1.90	4.38	4.54
ICGV 86031	2.11	5.79	8.24
SE ±	0.09	0.22	0.44
CD	NS	1.15**	2.30**
Fertilizer practices (F)			
No fertilizer	1.76	4.48	5.57
Farmer practice	2.02	4.94	6.21
Recommended practice	1.93	4.93	5.59
SE ±	0.08	0.18	0.39
CD	NS	NS	NS
Iron sprays (Fe)			
Nonsprayed control	1.72	4.38	5.80
Fe sprays	2.09	5.18	5.78
SE ±	0.07	0.10	0.19
CD	0.27**	0.39**	NS
Interactions			
SE ±			
F x G	0.16	0.34	0.62
F x Fe	0.11	0.22	0.45
G x Fe	0.13	0.25	0.50*
F x G x Fe	0.21	0.40	0.74

*, ** Significant at $P < 0.05$ and 0.01 level, respectively.

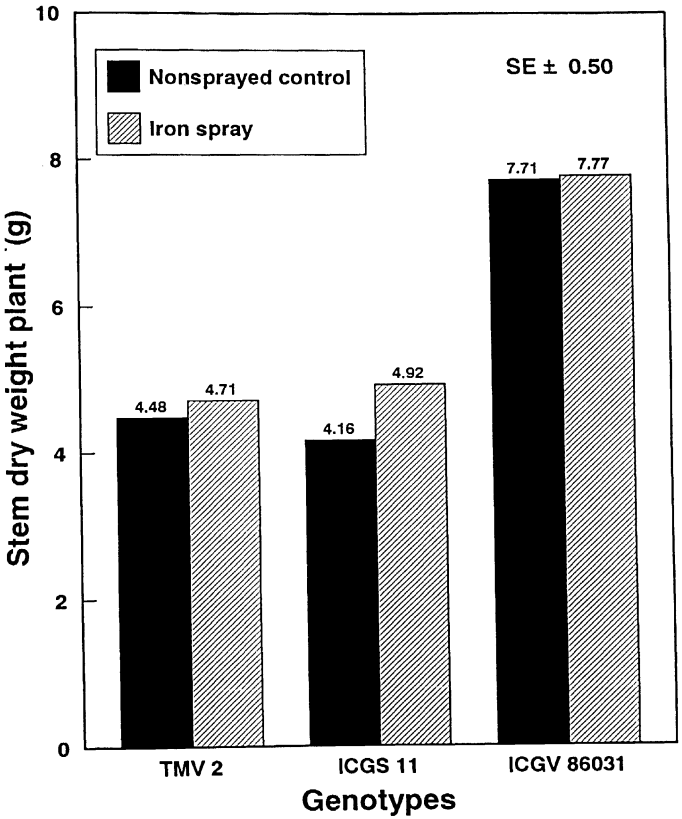


Figure 24. Interaction between genotypes and foliar iron sprays on groundnut stem dry weight plant^{-1} at final harvest.

Table 11. Mean root dry weight (g plant^{-1}) of groundnut genotypes under different fertilizer practices and foliar iron sprays at 60, 90 DAS and at final harvest.

Treatment	Days after sowing		
	60	90	Final harvest
Genotypes (G)			
TMV 2	0.197	0.386	0.428
ICGS 11	0.186	0.364	0.358
ICGV 86031	0.201	0.503	0.638
SE ±	0.007	0.022	0.040
CD	NS	0.115**	0.210**
Fertilizer practices (F)			
No fertilizer	0.199	0.426	0.482
Farmer practice	0.194	0.425	0.466
Recommended practice	0.196	0.401	0.477
SE ±	0.009	0.020	0.021
CD	NS	NS	NS
Iron sprays (Fe)			
Nonsprayed control	0.181	0.384	0.452
Fe sprays	0.208	0.451	0.498
SE ±	0.006	0.013	0.024
CD	0.023**	0.051**	NS
Interactions SE ±			
F x G	0.014	0.045	0.060
F x Fe	0.012	0.026	0.036
G x Fe	0.010	0.027	0.049
F x G x Fe	0.018	0.046	0.078

** Significant at $P < 0.05$ and 0.01 level, respectively.

4.2.2.6 Pod dry weight (g plant^{-1})

Pod dry weight plant^{-1} of groundnut genotypes varied significantly at all the growth stages (Table 12). ICGS 11 and ICGV 86031 recorded significantly higher pod dry weights than TMV 2 at 90 DAS and at final harvest. There was no significant effect of different fertilizer practices on groundnut pod dry weight at all the growth stages.

Foliar Fe sprays significantly increased pod dry weights of groundnut by 95% and 31% at 90 and at final harvest, respectively over nonsprayed control. Pod dry weight of groundnut was not significantly affected by various interactions between treatments at all the growth stages.

4.2.2.7 Total dry weight (g plant^{-1})

The genotypes varied significantly in their total dry weight plant^{-1} at all the growth stages (Table 13). ICGV 86031 produced significantly higher total dry weights (4.93) than TMV 2 (3.65) at 60 DAS. While at 90 and at final harvest the former genotype produced the maximum total plant dry weight than TMV 2 and ICGS 11. Different fertilizer practices had no significant effect on groundnut total plant dry weight at all the growth stages.

Foliar Fe sprays significantly increased total plant dry weights of groundnut by 23.5% and 16.5% at 60 and 90 DAS, respectively over nonsprayed control. The interactions were not significant at all the growth stages.

Table 12. Mean pod dry weight (g plant^{-1}) of groundnut genotypes under different fertilizer practices and foliar iron sprays at 60, 90 DAS and at final harvest.

Treatment	Days after sowing		
	60	90	Final harvest
Genotypes (G)			
TMV 2	0.036	1.35	3.55
ICGS 11	0.084	2.65	5.84
ICGV 86031	0.073	2.13	5.77
SE ±	0.009	0.11	0.18
CD	0.040*	0.58**	0.94**
Fertilizer practices (F)			
No fertilizer	0.068	2.27	5.09
Farmer practice	0.056	2.04	4.70
Recommended practice	0.071	1.83	5.37
SE ±	0.011	0.24	0.60
CD	NS	NS	NS
Iron sprays (Fe)			
Nonsprayed control	0.044	1.77	4.83
Fe sprays	0.086	2.32	5.58
SE ±	0.009	0.12	0.12
CD	0.035**	0.47**	0.47**
Interactions SE ±			
F x G	0.020	0.33	0.75
F x Fe	0.016	0.28	0.70
G x Fe	0.014	0.18	0.39
F x G x Fe	0.028	0.42	0.96

*,** = Significant at $P < 0.05$ and 0.01 level, respectively.

Table 13. Mean total plant dry weight (g plant^{-1}) of groundnut genotypes under different fertilizer practices and foliar iron sprays at 60, 90 DAS and at final harvest.

Treatment	Days after sowing		
	60	90	Final harvest
Genotypes (G)			
TMV 2	3.65	9.99	13.27
ICGS 11	4.11	11.74	15.20
ICGV 86031	4.93	14.77	22.97
SE ±	0.26	0.54	0.87
CD	1.15*	2.83**	4.56**
Fertilizer practices (F)			
No fertilizer	3.93	12.09	17.07
Farmer practice	4.50	12.62	17.27
Recommended practice	4.25	12.19	17.10
SE ±	0.21	0.38	0.93
CD	NS	NS	NS
Iron sprays (Fe)			
Nonsprayed control	3.78	11.24	16.88
Fe sprays	4.67	13.09	17.41
SE ±	0.14	0.29	0.002
CD	0.55**	1.14**	NS
Interactions SE ±			
F x G	0.40	0.81	1.40
F x Fe	0.27	0.52	1.89
G x Fe	0.31	0.64	1.14
F x G x Fe	0.50	1.01	1.89

*,** = Significant at $P < 0.05$ and 0.01 level, respectively.

4.2.2.8 Pod number plant^{-1}

The differences in pod number plant^{-1} among groundnut genotypes was significant at all the growth stages (Table 14). ICGV 86031 proved significantly superior to ICGS 11 and TMV 2 in pod number at all the growth stages. The pod number was not significantly affected by different fertilizer practices as well as foliar Fe sprays at all the growth stages.

None of the interactions between treatments was significant for total pod number plant^{-1} of groundnut at all the growth stages.

4.2.3 Nutrient concentration in plant parts

Data on mean concentration of various nutrients (macro and micro nutrients) in leaves and stem of groundnut genotypes under different fertilizer and foliar Fe sprays determined at 90 DAS are furnished in Tables 15 and 16.

4.2.3.1 Concentrations of macro nutrients (%)

4.2.3.1.1 Nitrogen concentration in leaf and stem

Nitrogen concentration in groundnut leaves was generally higher than stem (Table 15). Nitrogen concentration of groundnut genotypes differed significantly in leaves, but not in stem. ICGS 11 and ICGV 86031 accumulated significantly higher leaf nitrogen concentration than TMV 2.

Different fertilizer practices did not exhibit any effect on nitrogen concentration of groundnut leaves, while that of stem was affected significantly with higher values noticed

Table 14. Mean total pod number plant^{-1} of groundnut genotypes under different fertilizer practices and foliar iron sprays at 60, 90 DAS and at final harvest.

Treatment	Days after sowing		
	60	90	Final harvest
Genotypes (G)			
TMV 2	0.61	6.18	8.13
ICGS 11	1.40	10.78	16.78
ICGV 86031	0.86	9.13	18.41
SE ±	0.16	0.57	0.74
CD	0.71*	2.99**	3.88**
Fertilizer practices (F)			
No fertilizer	0.92	8.58	15.52
Farmer practice	1.07	8.68	13.86
Recommended practice	0.87	8.82	13.94
SE ±	0.16	0.70	0.71
CD	NS	NS	NS
Iron sprays (Fe)			
Nonsprayed control	0.62	7.50	14.51
Fe sprays	1.29	9.89	15.37
SE ±	0.11	0.43	0.71
CD	0.43**	1.68**	NS
Interactions SE ±			
F x G	0.33	1.12	1.17
F x Fe	0.21	0.88	1.12
G x Fe	0.26	0.78	1.14
F x G x Fe	0.41	1.53	1.91

* = Significant at $P < 0.05$ and 0.01 level, respectively.

Table 15. Mean concentration of major and secondary nutrients (%) in leaves and stem of groundnut genotypes under different fertilizer practices and foliar iron sprays at 90 days after sowing.

Treatments	N		P		K		Ca		Mg	
	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem
Genotypes (G)										
TMV 2	2.757	1.695	0.225	0.228	0.892	1.170	2.724	1.517	1.250	1.517
ICGS 11	3.086	1.804	0.201	0.202	0.832	1.101	2.371	1.251	1.210	1.277
ICGV 86031	3.076	1.706	0.194	0.192	0.983	1.191	2.281	0.973	0.980	1.074
SE ±	0.064*	1.051	0.005	0.005	0.020	0.045	0.069	0.045	0.225	0.043
CD	0.284*	NS	0.022*	0.022*	NS	NS	NS	0.236**	NS	0.225**
Fertilizer practices (F)										
No fertilizer	2.833	1.573	0.190	0.189	0.818	1.059	2.625	1.244	0.990	1.247
Farmer practice	3.079	1.934	0.227	0.228	0.926	1.181	2.350	1.213	1.090	1.343
Recommended practice	3.006	1.698	0.203	0.205	0.963	1.222	2.601	1.283	1.360	1.278
SE ±	0.093	0.048	0.010	0.006	0.068	0.056	0.123	0.028	0.257	0.039
CD	NS	0.147*	NS	0.026*	NS	NS	NS	NS	NS	NS
Iron sprays (Fe)										
Nonsprayed control	2.919	1.724	0.210	0.209	0.901	1.151	2.576	1.249	1.260	1.308
Fe sprays	3.026	1.746	0.203	0.207	0.904	1.157	2.475	1.245	1.040	1.270
SE ±	0.029	0.030	0.004	0.005	0.024	0.032	0.065	0.019	0.189	0.021
CD	0.084*	NS	NS	NS	NS	NS	NS	NS	NS	NS

*, ** = Significant at $P < 0.05$ and 0.01 level, respectively.

under farmer fertilizer practice than no fertilizer control and recommended fertilizer practice.

Foliar Fe sprays significantly increased leaf nitrogen concentration of groundnut by 3.66% over nonsprayed control. Interactions between the treatments were nonsignificant for nitrogen concentration in groundnut leaves and stem.

4.2.3.1.2 Phosphorus concentration in leaf and stem

Phosphorus concentration in leaves of groundnut was similar to stem (Table 15). Phosphorus concentration in leaves and stem of groundnut genotypes varied significantly. TMV 2 contained significantly higher leaf and stem phosphorus concentrations than ICGS 11 and ICGV 86031.

There was no significant effect of different fertilizer practices on groundnut leaf phosphorus concentration. Whereas, stem phosphorus concentration of groundnut under farmer fertilizer practice or recommended fertilizer practice was significantly higher than no fertilizer control.

Foliar Fe sprays did not significantly influence phosphorous concentration in groundnut leaves and stem.

Interaction between fertilizer practices and genotypes was significant only for phosphorus concentration in stem (Fig. 25). TMV 2 when grown under farmer fertilizer practice accumulated the highest phosphorus concentration in stem. While the lowest stem phosphorus concentration was noticed for ICGV 86031 under no fertilizer control or recommended fertilizer practice.

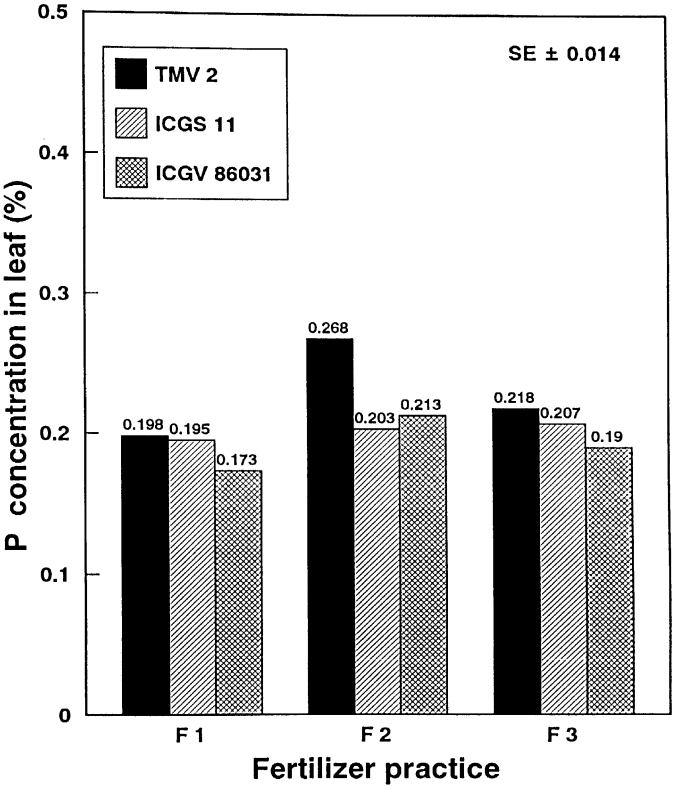


Figure 25. Interaction between fertilizer practices and genotypes on phosphorus (P) concentration (%) in stem of groundnut at 90 DAS.

4.2.3.1.3 Potassium concentration in leaf and stem

Potassium concentration in groundnut stem was always more than leaves (Table 15). Potassium concentration in leaves and stems of groundnut was not significantly by variable among different genotypes, fertilizer practices, and foliar Fe sprays.

Similarly, none of the interaction between treatments was significant for potassium concentration in groundnut leaves and stem.

4.2.3.1.4 Calcium concentration in leaf and stem

Calcium concentration in groundnut leaves was generally higher than stem (Table 15). Calcium concentration in leaves of groundnut genotypes did not vary significantly, but it varied significantly in stem. TMV 2 gathered significantly higher calcium concentration in stem than that of ICGS 11 and ICGV 86031.

Different fertilizer practices as well as foliar sprays did not significantly affect calcium concentration in groundnut leaves and stem.

None of the interaction between treatments was significant for calcium concentration in groundnut leaves and stem.

4.2.3.1.5 Magnesium concentration in leaf and stem

Magnesium concentration in groundnut leaves was similar to stem (Table 15). Magnesium concentration in leaves of groundnut genotypes did not vary significantly, but for that of stem, TMV 2 had significantly higher magnesium concentration in stem than ICGS 11 and ICGV 86031. The same was not significantly influenced by different fertilizer

practices and foliar Fe sprays on magnesium concentration in groundnut leaves and stem.

None of the interactions between treatments was significant for magnesium concentration in groundnut leaves and stem.

4.2.3.2 Concentration of micro nutrients (ppm)

4.2.3.2.1 Total Fe concentration in leaf and stem

Total Fe concentration in groundnut stem was generally higher than in leaves (Table 16). Total Fe concentration in leaves and stems of groundnut genotypes varied significantly. ICGS 11 showed significantly higher total Fe concentration in leaves and stem than ICGV 86031 and TMV 2. There was no significant effect of different fertilizer practices on total Fe concentration in groundnut leaves and stem.

Foliar Fe sprays significantly increased total Fe concentration in leaves and stem of groundnut by 320% and 42.3%, respectively over nonsprayed control.

Total Fe concentration in groundnut stem was significantly influenced interaction between genotypes, fertilizer practices, and Fe sprays (Fig. 26). Where, ICGV 86031 under no fertilizer control with foliar Fe sprays reflected in the highest total Fe concentration (579).

4.2.3.2.2 Zinc concentration in leaf and stem

Zinc concentration in groundnut leaves was similar to stem (Table 16). Zinc concentration in groundnut leaves and stem was not significantly influenced by the main and interaction effects of genotypes, fertilizer practices, and foliar Fe sprays.

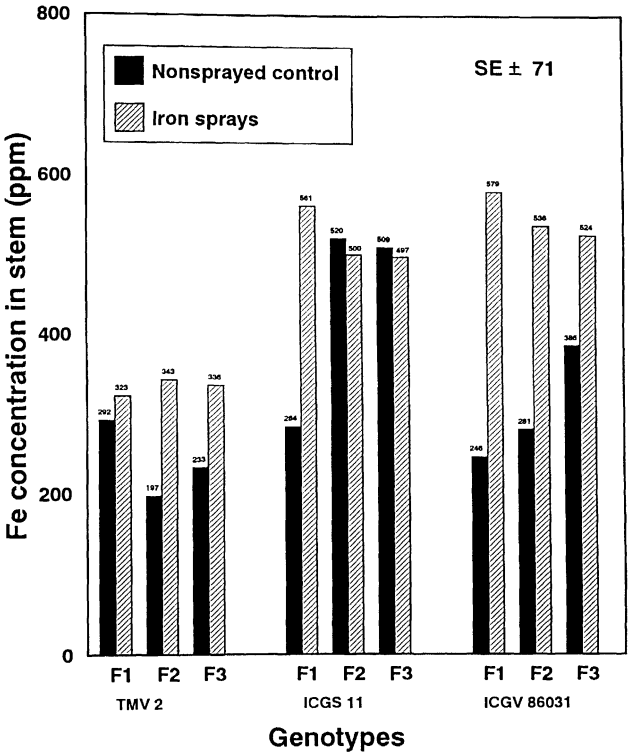


Figure 26. Interaction between fertilizer practices, genotypes and foliar iron sprays on Fe concentration in groundnut stem at 90 DAS.

Table 16. Mean concentration of micronutrients (ppm) in leaves and stem of groundnut genotypes under different fertilizer practices and foliar iron sprays at 90 days after sowing.

Treatment	Fe		Zn		Cu		Mn	
	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem
Genotypes (G)								
TMV 2	337.0	228	6.4	6.79	9.4	4.08	21.1	1.05
ICGS 11	388.0	470	8.2	7.27	7.9	4.51	34.3	1.87
ICGV 86031	289.0	425	7.1	6.02	6.6	3.98	31.4	1.77
SE ±	10.2	34	0.9	0.68	0.2	0.25	3.1	0.08
CD	53.5*	151.1*	NS	NS	1.0**	NS	NS	0.42**
Fertilizer practices (F)								
No fertilizer	331.0	381	6.5	7.05	8.3	4.62	30.5	1.59
Farmer practice	323.0	330	7.1	6.48	7.7	3.99	30.3	1.60
Recommended practice	361.0	381	8.4	6.56	7.8	3.96	26.6	1.49
SE ±	23.4	19	1.0	0.72	0.3	0.22	1.4	0.07
CD	NS	NS	NS	NS	NS	NS	NS	NS
Iron sprays (Fe)								
Nonsprayed control	130.0	328	7.2	7.01	7.8	4.18	31.4	1.54
Fe sprays	546.0	467	7.2	6.38	8.1	4.20	26.4	1.58
SE ±	155.0	22	1.1	0.39	0.1	0.09	1.0	0.06
CD	61.73*	86.2**	NS	NS	NS	NS	3.9*	NS

*, ** = Significant at $P < 0.05$ and 0.01 level, respectively.

4.2.3.2.3 Copper concentration in leaf and stem

Copper concentration in groundnut leaves was double the concentration in stem (Table 16). Copper concentration in leaves of groundnut genotypes varied significantly, TMV 2 being significantly superior in its copper concentration to ICGS 11 and ICGV 86031. Copper concentration in stem of groundnut genotypes did not vary significantly.

There was no significant effect of different fertilizer practices or foliar Fe sprays on copper concentration in groundnut leaves and stem.

Similarly, none of the interaction between treatments was significant for copper concentration in groundnut leaves and stem.

4.2.3.2.4 Manganese concentration in leaf and stem

Manganese concentration in groundnut leaves was 10 to 15 times more than in stem (Table 16). Groundnut genotypes did not vary significantly in their leaf Mn concentration, whereas its concentration in stem varied significantly (Table 16). ICGS 11 & ICGV 86031 accumulated significantly more stem manganese than TMV 2.

There was no significant effect of different fertilizer practices on manganese concentration in groundnut leaves and stem. Foliar Fe sprays significantly decreased manganese concentration in groundnut leaves by 14.6% over nonsprayed control (26.4).

Interaction between genotypes and Fe sprays significantly influenced manganese concentration in groundnut leaves (Fig. 27). TMV 2 with foliar Fe sprays recorded the lowest manganese contention in leaves. Highest leaf manganese concentration was recorded by ICGS 11 with foliar Fe sprays (38.28).

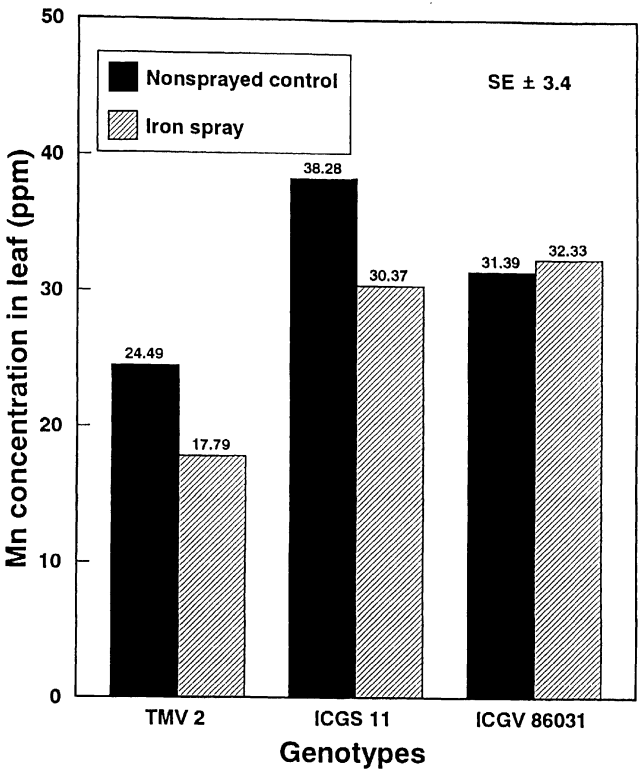


Figure 27. Interaction between genotypes and foliar iron sprays on leaf manganese (Mn) concentration (ppm) in groundnut at 90 DAS.

4.2.4 Nutrient uptake by plant parts

Data on mean nutrient uptake by leaves and stem of groundnut genotypes under different fertilizer practices and foliar Fe sprays at 90 DAS are given in Tables 17 and 18.

4.2.4.1 Uptake of macro nutrients (mg plant^{-1})

4.2.4.1.1 Uptake of nitrogen by leaf and stem

Nitrogen uptake by leaves was generally higher than by stem (Table 17). Nitrogen uptake by leaves and stem of groundnut varied significantly among genotypes, fertilizer practices, and foliar Fe sprays. ICGV 86031 recorded significantly more nitrogen uptake by leaves and stem than TMV 2. Whereas, ICGS 11 was found intermediate in nitrogen uptake by leaves and stem.

Nitrogen uptake by leaves and stem under farmer fertilizer practice was significantly higher than the recommended fertilizer practice and no fertilizer control. However, nitrogen uptake by stem under farmer fertilizer practice and recommended fertilizer practice was at par.

Foliar Fe sprays significantly increased the nitrogen uptake by groundnut stem by 19.8% the over nonsprayed control (75.5). None of the interactions between treatments was significant for nitrogen uptake by groundnut leaves and stem.

4.2.4.1.2 Uptake of phosphorus by leaf and stem

Phosphorus uptake by groundnut leaves was similar to stem (Table 17). Phosphorus uptake by leaves and stem of groundnut genotypes varied significantly. ICGV

Table 17. Mean uptake (mg plant^{-1}) of major and secondary nutrients by leaves and stem of groundnut genotypes under different fertilizer practices and foliar iron sprays at 90 days after sowing.

Treatments	N		P		K		Ca		Mg	
	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem
Genotypes (G)										
TMV 2	112.7	70.6	9.2	9.5	36.4	48.7	111.4	63.2	51.1	63.2
ICGS 11	134.2	79.0	8.7	8.8	36.2	48.2	103.1	54.7	52.6	55.9
ICGV 86031	195.5	98.7	12.3	11.1	62.4	68.9	144.4	56.3	62.2	62.1
SE ±	13.0	5.2	0.7	0.5	4.2	3.1	4.8	3.0	11.0	3.0
CD	57.8*	23.1*	3.1*	2.2*	18.7*	1.4*	25.1**	NS	NS	NS
Fertilizer practices (F)										
No fertilizer	139.3	70.4	9.3	8.4	40.3	47.4	129.1	55.7	48.7	55.8
Farmer practice	161.0	95.5	11.8	11.3	48.4	58.3	123.0	59.9	57.0	66.33
Recommended practice	139.4	83.7	9.4	10.1	44.6	60.2	120.4	63.2	63.1	63.7
SE ±	5.6	4.1	0.5	0.6	3.7	3.4	7.2	3.4	13.6	2.7
CD	24.9*	18.2*	NS	2.7*	NS	NS	NS	NS	NS	NS
Iron sprays (Fe)										
Nonsprayed control	121.7	75.5	8.7	9.1	37.6	50.4	107.4	54.7	52.5	57.2
Fe sprays	155.8	90.4	10.5	10.7	46.5	59.9	127.4	64.5	53.5	65.7
SE ±	6.6	2.7	0.4	3.8	2.8	2.2	5.5	1.7	10.2	1.5
CD	NS	10.6*	NS	1.1*	NS	6.4*	NS	6.7**	NS	5.9**

*, ** = Significant at $P < 0.05$ and 0.01 level, respectively.

86031 recorded significantly higher nitrogen uptake by leaves and stem than TMV 2 and ICGS 11.

There was no significant effect of different fertilizer practices on phosphorus uptake by leaves of groundnut. Whereas, phosphorus uptake by stem under farmers fertilizer practice (11.3) and recommended fertilizer practice (10.1) was significantly higher than no fertilizer control (8.4).

Foliar Fe sprays significantly increased phosphorus uptake by groundnut stem by 17.5% over nonsprayed control (9.1). None of the interaction between treatments was significant for phosphorus uptake by groundnut leaves and stem.

4.2.4.1.3 Uptake of potassium by leaf and stem

Potassium uptake by groundnut stem was generally higher than leaves (Table 17). ICGV 86031 recorded significantly higher potassium uptake by leaves and stem than TMV 2 and ICGS 11. There was no significant effect of different fertilizer practices on potassium uptake by groundnut leaves and stem.

Foliar Fe sprays significantly increased potassium uptake only in stem by 18.8% over nonsprayed control (50.4). None of the interaction between treatments was significant for potassium uptake by groundnut leaves and stem.

4.2.4.1.4 Uptake of calcium by leaf and stem

Calcium uptake by groundnut leaves was double the stem (Table 17). Calcium uptake by leaves of groundnut genotypes varied significantly. ICGV 86031 recorded

significantly more calcium uptake by leaves than TMV 2 and ICGS 11. Calcium uptake by stem of groundnut genotype did not vary significantly. There was no significant effect of different fertilizer practices on calcium uptake by groundnut leaves and stem.

Foliar Fe sprays significantly increased calcium uptake only by groundnut stem by 17.9% over nonsprayed control (54.7). None of the interactions between the treatments was significant for calcium uptake by groundnut leaves and stem.

4.2.4.1.5 Uptake of magnesium by leaf and stem

Magnesium uptake by groundnut leaves was similar to that of stem (Table 17). Magnesium uptake by leaves and stem of groundnut did not vary significantly among genotypes or fertilizer practices.

Foliar Fe sprays significantly increased the magnesium uptake of groundnut stem by 14.8% over nonsprayed control (57.2). None of the interactions between treatments was significant for magnesium uptake by groundnut leaves and stem.

4.2.4.2 Uptake of micro nutrients (μ g plant^{-1})

4.2.4.2.1 Uptake of total Fe by leaf and stem

Total Fe uptake by groundnut stem was relatively higher than leaves (Table 18). Total Fe uptake by leaves of groundnut genotypes did not vary significantly, but its uptake by stem varied significantly. ICGV 86031 recorded significantly higher Fe uptake by stem than ICGS 11 and TMV 2. There was no significant effect of different fertilizer practices on Fe uptake by groundnut leaves and stem.

Table 18. Mean micronutrient uptake (μg plant^{-1}) by leaves and stem of groundnut genotypes under different fertilizer practices and foliar iron sprays at 90 days after sowing.

Treatments	Fe		Zn		Cu		Mn	
	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem
Genotypes (G)								
TMV 2	1378	1200	26.10	28.31	38.40	17.01	86.3	4.38
ICGS 11	1687	2058	35.70	31.84	34.40	19.75	149.5	8.19
ICGV 86031	1835	2460	45.08	34.84	41.90	23.04	199.4	10.24
SE ±	130	236	3.09	1.91	3.56	1.21	32.8	0.51
CD	NS	1048*	13.73*	NS	NS	5.38*	NS	2.67**
Fertilizer practices (F)								
No fertilizer	1628	1706	31.98	31.58	40.83	20.69	150.0	7.12
Farmer practice	1689	1630	37.13	32.01	40.27	19.71	158.5	7.90
Recommended practice	1675	1878	38.97	32.34	36.19	19.52	123.4	7.34
SE ±	80	159	3.39	3.32	0.86	1.44	11.9	0.41
CD	NS	NS	NS	NS	4.51**	NS	NS	NS
Iron sprays (Fe)								
Nonsprayed control	542	1436	30.02	30.70	32.52	18.30	130.9	6.74
Fe sprays	2811	2419	37.08	33.04	41.71	21.75	138.0	8.18
SE ±	60	130	4.68	1.75	1.36	0.71	13	0.44
CD	23.5**	509*	NS	NS	3.95*	2.78*	NS	1.28*

*, ** = Significant at $P < 0.05$ and 0.01 level, respectively.

Foliar Fe sprays significantly increased Fe uptake by groundnut leaves and stem by 133% and 68%, respectively over nonsprayed control.

Interaction between genotypes and Fe sprays significantly influenced Fe uptake by stem (Fig. 28). ICGV 86031 with foliar Fe sprays recorded highest Fe uptake, and the lowest Fe uptake was recorded by TMV 2 with no Fe sprays. Similarly, ICGV 86031 grown under farmer fertilizer practice and provided with Fe sprays recorded the maximum Fe uptake (Fig. 29). In general, ICGV 86031 and ICGS 11 were more efficient than TMV 2 for Fe uptake grown under different fertilizer practices and provided with foliar Fe sprays.

4.2.4.2.2 Uptake of zinc by leaf and stem

Zinc uptake groundnut leaves was relatively higher than stem (Table 18). Zinc uptake by leaves of groundnut genotypes varied significantly. ICGV 86031 recorded significantly higher zinc uptake by leaves than TMV 2. While ICGS 11 was intermediate for zinc uptake. Zinc uptake by stem of groundnut genotypes did not vary significantly.

There was no significant effect of different fertilizer practices or foliar Fe sprays on zinc uptake by groundnut leaves and stem. None of the interaction between treatments was significant for zinc uptake by groundnut leaves and stem.

4.2.4.2.3 Uptake of copper by leaf and stem

Copper uptake by groundnut leaves was about twice the uptake by stem (Table 18). Copper uptake by leaves of groundnut genotypes did not vary significantly, but its

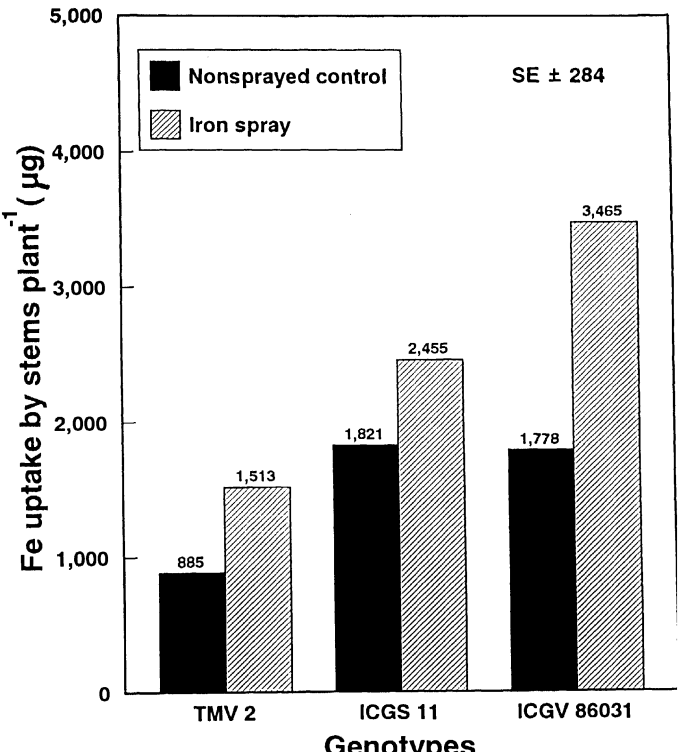


Figure 28. Interaction between genotypes and foliar iron sprays on Fe uptake by groundnut stem at 90 DAS.

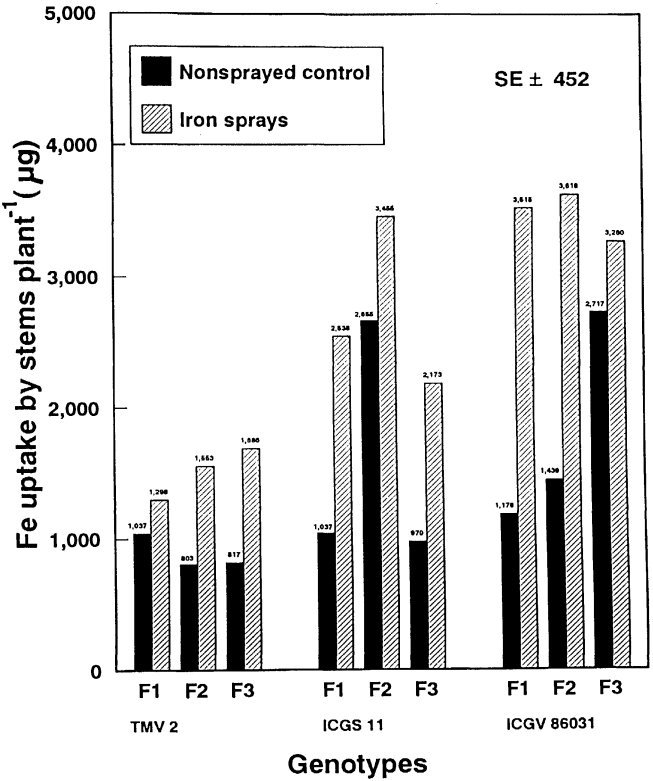


Figure 29. Interaction between fertilizer practices, genotypes and foliar iron sprays on Fe uptake by groundnut stem at 90 DAS.

uptake by stem differed significantly. ICGV 86031 recorded significantly higher copper uptake by stem than TMV 2. While, copper uptake by stem of ICGS 11 was intermediate.

Copper uptake by leaves of groundnut under different fertilizer practices varied significantly, but its uptake by stem was not significant. Copper uptake by groundnut leaves under no fertilizer control was significantly higher than the recommended fertilizer practice. Whereas, its uptake under farmer fertilizer practice was intermediate.

Foliar Fe sprays significantly increased copper uptake by groundnut leaves and stem by 28.2% and 18.8%, respectively over nonsprayed control.

Interaction between genotypes, fertilizer practices, and foliar Fe sprays was significant only for copper uptake by groundnut stem (Fig. 30). Where, ICGV 86031 under no fertilizer control and provided with foliar Fe sprays recorded the highest copper uptake by stem. While, the lowest copper uptake by stem was found in ICGS 11 and TMV 2 grown under recommended fertilizer practice with no Fe sprays.

4.2.4.2.4 Uptake of manganese by leaf and stem

Manganese uptake by groundnut leaves was about 15 to 20 times more than its uptake by stem (Table 18). Manganese uptake by leaves of groundnut was influenced significantly by genotypes and foliar Fe sprays.

ICGV 86031 and ICGS 11 recorded significantly higher manganese uptake by stem than TMV 2. Foliar Fe sprays significantly increased manganese uptake by groundnut stem by 21.3% over nonsprayed control. None of the interactions between treatments was significant for manganese uptake by groundnut leaves and stem.

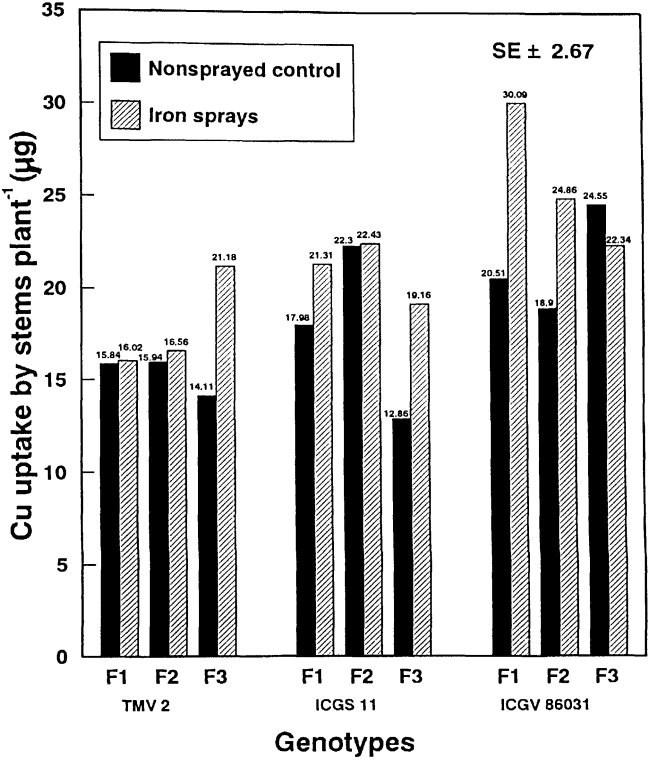


Figure 30. Interaction between fertilizer practices genotypes and foliar iron sprays on copper (Cu) uptake by groundnut stem at 90 DAS.

4.2.5 Yield and yield attributes

4.2.5.1 Yield (kg ha^{-1})

4.2.5.1.1 Haulm yield

Highly significant differences in haulm yields were noticed among groundnut genotypes (Fig. 31a). ICGV 86031 produced the maximum haulm yield (4371) followed by ICGS 11 (3508) and TMV 2 (2795).

There was no significant effect of different fertilizer practices on haulm yield of groundnut (Fig. 31b). However, recommended fertilizer practice produced relatively more haulm yield than no fertilizer control or farmer fertilizer practice.

Foliar Fe sprays did not significantly influence haulm yield of groundnut (Fig. 31c). Similarly, none of the interactions between treatments was significant for haulm yield of groundnut.

4.2.5.1.2 Dry pod yield

Pod yield of groundnut genotypes varied significantly (Fig. 31a), where ICGS 11 (1522) and ICGV 86031 (1451) gave significantly higher dry pod yields than TMV 2 (921). Pod yield was not significantly influenced by different fertilizer practices (Fig. 31 b).

Foliar Fe sprays significantly increased pod yield of groundnut by 20.3% over the nonsprayed control (1179). None of the interactions between treatments was found significant for dry pod yield of groundnut.

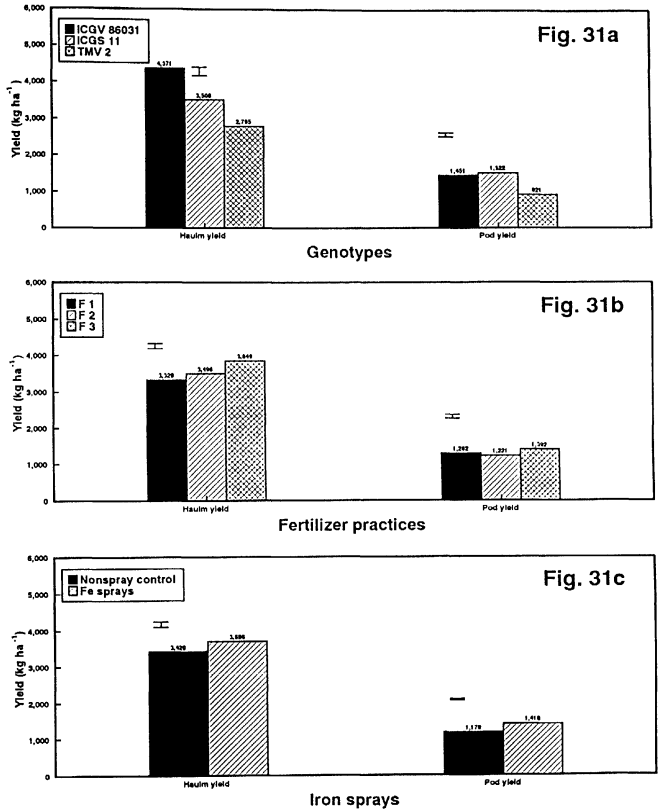


Figure 31. Haulm and pod yields of groundnut genotypes under different fertilizer practices and foliar iron sprays.

4.2.5.1 Yield attributes

4.2.5.1.1 Harvest index (%)

Harvest index (HI) of groundnut was not significantly influenced by different genotypes, fertilizer practices, and foliar Fe sprays (Table 19).

None of the interaction between treatments was significant for HI of groundnut.

4.2.5.1.2 Shelling percentage

Shelling percentage of groundnut was significantly influenced only by genotypes (Table 19). Where, ICGS 11 gave significantly more shelling percentage (64.83%) than TMV 2 (61.78%) and ICGV 86031 (52.79%). There was no significant effect of different fertilizer practice and foliar Fe sprays on shelling percentage of groundnut.

None of the interactions between treatments was significant for shelling percentage of groundnut.

4.2.5.1.3 Test weight (g 100 seed^{-1})

Test weight of groundnut responded similar to shelling percentage (Table 19). ICGS 11 and ICGV 86031 gave significantly higher test weights (41.74 and 39.85 g 100 seed^{-1}, respectively) than TMV 2 (29.47 g 100 seed^{-1}). None of the interactions between treatments was significant for test weight of groundnut.

Table 19. Mean yield and yield parameters of groundnut genotypes under different fertilizer practices and foliar iron sprays.

Treatment	Dry yields kg ha^{-1}			HI %	Shelling %	Test weight (g)
	Haulm	Pod	TDM			
Genotypes (G)						
TMV 2	2795	921	3716	24.93	61.78	29.47
ICGS 11	3508	1522	5031	30.37	64.83	41.74
ICGV 86031	4371	1451	5822	25.32	52.79	39.85
SE ±	223	104	294	1.53	1.47	0.93
CD	1166**	462*	1540**	NS	7.7**	4.86**
Fertilizer practices (F)						
No fertilizer	3329	1282	4611	28.04	60.99	38.06
Farmer practice	3496	1221	4717	26.22	57.63	36.10
Recommended practice	3849	1392	5241	26.36	60.78	36.90
SE ±	139	91	162	1.63	1.11	1.39
CD	NS	NS	NS	NS	NS	NS
Iron sprays (Fe)						
Nonsprayed control	3420	1179	4598	26.03	59.87	36.92
Fe sprays	3696	1418	5114	27.71	59.73	37.12
SE ±	147	49	186	0.66	0.66	0.75
CD	NS	192.4**	NS	NS	NS	NS
Interactions SE ±						
F x G	382	169	500	2.33	2.07	1.85
F x Fe	228	109	279	1.82	1.38	1.67
G x Fe	287	120	372	1.72	1.68	1.31
F x G x Fe	494	198	637	2.71	2.51	2.44

*, ** = Significant at $P < 0.05$ and 0.01 level, respectively.

4.2.6 Qualitative analysis

4.2.6.1 Oil content (%)

Oil content of groundnut was significantly influenced by different genotypes and fertilizer practices (Table 20). ICGV 86031 exhibited significantly higher oil content (52.83%) than in ICGS 11 (49.95%) and TMV 2 (47.45%).

Recommended fertilizer practice and no fertilizer practice gave significantly higher oil content (50.53 and 50.41%, respectively) than farmer fertilizer practice (49.30%).

Oil content of groundnut was not influenced significantly by foliar Fe sprays. However, foliar Fe sprays improved oil content of groundnut by 2% over the nonsprayed control. None of the interaction between treatments was found significant for oil content of groundnut.

4.2.6.2 Protein content (%)

Protein content in groundnut kernels was significantly influenced by genotypes (Table 20). TMV 2 contained the maximum protein content (27%) which was followed by ICGV 86031 (25.43%) and ICGS 11 (23.7%).

Different fertilizer practices or foliar Fe sprays did not significantly improve protein content of groundnut. Similarly, none of the interaction between treatments was significant for protein content.

Table 20. Mean oil and protein content (%) in kernel of groundnut genotypes under different fertilizer practices and foliar iron sprays.

Treatment	Oil content (%)	Protein content (%)
Genotypes (G)		
TMV 2	47.45	27.00
ICGS 11	49.95	23.70
ICGV 86031	52.83	25.43
SE ±	0.21	0.15
CD	1.09**	0.78**
Fertilizer practices (F)		
No fertilizer	50.41	25.20
Farmer practice	49.30	26.05
Recommended practice	50.53	24.95
SE ±	0.29	1.39
CD	1.29*	NS
Iron sprays (Fe)		
Nonsprayed control	49.31	25.25
Fe sprays	50.31	25.45
SE ±	0.18	0.18
CD	NS	NS
Interactions		
SE ±		
F x G	0.41	0.43
F x Fe	0.36	0.35
G x Fe	0.30	0.26
F x G x Fe	0.56	0.57

*, ** = Significant at $P < 0.05$ and 0.01 level, respectively.

4.2.7 Economic analysis

The results of the economic analysis revealed that the overall mean treatment wise pooled cost of cultivation for groundnut production amounted to Rs. 7748 ha^{-1}.

The various economic variables (gross and net monetary returns and B/C ratio) varied significantly among all the experimental treatments (Table 21).

Among genotypes, ICGS 11 gave the highest gross (Rs. 16219 ha^{-1}), net (Rs. 8542 ha^{-1}) returns and B/C ratio (1.24) followed by ICGV 86031. Whereas TMV 2, gave the lowest gross (Rs. 9992 ha^{-1}), net (Rs. 2224 ha^{-1}) returns and B/C ratio (0.31).

Farmers fertilizer practice was found significantly inferior to other fertilizer practices for all the economic variables. No fertilizer control gave the highest B/C ratio (1.34), whereas recommended fertilizer practice gave maximum gross (Rs. 15024 ha^{-1}) and net (Rs. 7984 ha^{-1}) monetary returns.

Foliar Fe sprays were found highly remunerative and gave net returns of Rs. 7400 ha^{-1} with a B/C ratio of 1.06. The total cost involved in Fe sprays was Rs. 245 ha^{-1} and gave the additional benefit of Rs. 2316 ha^{-1} over the nonsprayed control.

Table 21. Total gross and net monetary returns and benefit/cost ratio (B/C ratio) for groundnut genotypes under different fertilizer practices and foliar iron sprays.

Treatments	Gross returns (Rs)	Net returns (Rs)	B/C ratio
Genotypes (G)			
TMV 2	9992	2243	0.37
ICGS 11	16291	8542	1.24
ICGV 86031	15737	7989	1.14
SE±	1092	1092	0.16
CD	4851*	4851*	0.71*
Fertilizer practices (F)			
No fertilizer	13795	7902	1.34
Farmer practice	13201	2888	0.28
Recommended practice	15024	7984	1.13
SE±	927	927	0.13
CD	NS	4116*	0.68**
Iron sprays (Fe)			
Nonsprayed control	12753	5116	0.77
Fe sprays	15024	7400	1.06
SE±	525	525	0.08
CD	2046**	2146**	0.23*

* = Significant at $P < 0.05$ and 0.01 level, respectively.

DISCUSSION

CHAPTER V

DISCUSSION

Iron chlorosis is one of the major nutritional constraints to groundnut production in the Rayalseema region of Andhra Pradesh. Many other crops have been reported to suffer from Fe chlorosis in several parts of India (Kannan, 1988). Iron plays an important role in a series of metabolic activities involving respiratory enzymes and various photosynthetic reactions in plant systems. Iron deficiency in plants typically causes chlorosis of leaf tissue because of inadequate chlorophyll synthesis (Chen and Barak, 1982). Iron chlorosis is especially evident in crops grown on calcareous-alkaline soils and can cause loss of stand and decreased yields under severe Fe deficient conditions (Mortvedt, 1975).

Among legumes, groundnut is highly susceptible to Fe chlorosis which adversely affects its growth and productivity (Potdar and Anders, 1993). Results from recent on-farm trials conducted in Andhra Pradesh and Maharashtra by ICRISAT (RMP Annual Report 1993) indicated that Fe chlorosis can cause pod yield losses as high as 46% in groundnut.

Indian soils are generally rich in total Fe content, however this Fe is not present in a form which plants can utilize. In calcareous and alkaline soils, Fe is present mostly in ferric form and other insoluble forms which are not readily available to many plants. Several factors including free $CaCO_3$, high HCO_3^-, high soil pH, sodic soils, high phosphorous content, temperature extremes, heavy manuring, root damages, viruses and genetic differences are responsible for Fe chlorosis (Brown, 1961; Chen and Barak, 1982;

Vose, 1982). These factors can act independently or in combination which makes management of Fe chlorosis difficult under on-farm conditions. Farmer crop management practices may strongly influence the Fe availability. These management practices are generally related to how the farmers perceive the problem of Fe chlorosis. Therefore, knowledge of farmer perceptions and management practices for Fe chlorosis would help in accurate diagnosis of the problem and the development of appropriate management strategies to alleviate the problem.

In the present study, initial surveys were conducted in Kottapeta and Pasupalla villages in Kurnool district of Andhra Pradesh, where groundnut often suffers from Fe chlorosis. Based on these survey results, a follow-up diagnostic on-farm trial was conducted which evaluated different genotypes, fertilizer practices, and foliar Fe sprays for correcting of Fe chlorosis.

Village surveys

Survey results revealed that farmers prefer to grow groundnut on deep Vertisols with medium to high fertility (Figs. 3 to 5). Local genotype (cv. TMV 2) was predominantly grown in these villages. This genotype is known to suffer from Fe chlorosis (Potdar and Anders, 1992; Reddy *et al.*, 1993). The crop is generally fertilized with high doses of nitrogenous fertilizers (100-200 kg N ha^{-1}) in 2 to 4 splits (Fig. 10). However, this practice is contradictory to the recommended fertilizer practice in Andhra Pradesh where nitrogen is recommended at a rate of 20 kg N ha^{-1} (Basu and Reddy, 1989).

Farmers in these villages identified Fe chlorosis as one of the major production constraints in groundnut and estimated yield losses to be between 20 to 40% (Fig. 12). Similar yield losses due to Fe chlorosis have been observed in several groundnut field studies (Bhaskar, 1990; Potdar and Anders, 1992; Reddy *et al.*, 1993).

Iron chlorosis was more severe in Pasupalla than in Kottapeta. Farmers related the incidence of Fe chlorosis to irrigation practices and soil types. Iron chlorosis can occur in patches or uniform chlorosis spread throughout the field. However, patchy occurrence of Fe chlorosis was more common than uniform chlorosis spread throughout the field. Excess irrigation and/or waterlogging conditions are known to induce Fe chlorosis in groundnut (Singh *et al.*, 1987; Reddy *et al.*, 1993; Potdar and Anders, 1993).

Farmers' perceptions about causes of Fe chlorosis did not vary among farmer groups or between villages (Fig. 13). Farmers perceived low soil fertility, high soil lime content, high soil alkalinity, excess irrigation and waterlogging, and nitrogen deficiency as the main factors influencing Fe chlorosis in groundnut. These results showed that farmers were aware of the main causes of Fe chlorosis. However, farmers often mistook Fe chlorosis symptoms as nitrogen deficiency, and responded with doses of nitrogen fertilizer as high as 200 kg N ha^{-1} provided through different fertilizers. Nitrogen fertilizer sources were Urea, DAP, Gromor, 17:17:17, and Calcium ammonium nitrate. The form of nitrogen (NH_4 or NO_3) applied may affect the availability of soil Fe to plants and conversion within the plant. Increased NO_3-N uptake may cause an imbalance in the cation/anion balance ratio, resulting in the exudation of HCO_3^- into the rhizosphere with a subsequent reduction in Fe uptake (Chen and Barak, 1982). Such high doses of nitrogen not only enhances Fe

chlorosis but also can adversely affect nodulation (Nambiar, 1990). Poor nodulation was observed in many groundnut plots in these villages.

These survey results indicated that calcareous and alkaline soil properties, use of Fe inefficient genotype, irrigation by flooding method, and use of high doses of nitrogen were the main causes of Fe chlorosis in groundnut. However, further studies are needed for accurate diagnosis of this nutrient disorder. In some fields where severe Fe chlorosis occurred farmers were replacing groundnut with sunflower which is considered as tolerant to Fe chlorosis. In order to sustain groundnut production in Andhra Pradesh, it is inevitable that Fe efficient groundnut genotype be developed and/or appropriate management practices be adopted which will to prevent yield losses due to Fe chlorosis.

Village surveys assisted in designing an on-farm trial which evaluated the role of an Fe efficient genotype (ICGV 86031), different fertilizer practices and foliar Fe sprays for the correction of Fe chlorosis.

On-farm trial

Genotypic differences

In the present experiment, TMV 2 and ICGS 11 exhibited typical Fe chlorosis symptoms as described by Agarwala and Sharma (1979) within 20 DAS. However, ICGV 86031 remained dark green throughout its growth. TMV 2 and ICGS 11 have been identified as Fe inefficient in the studies at ICRISAT (RMP Annual Report, 1993). Groundnut genotypes are known to vary for their tolerance to Fe chlorosis (Kannan, 1982; Singh and Vidya Chaudhari, 1991; Reddy *et al.*, 1993).

Chlorosis symptoms disappeared within 5 days after foliar application of $FeSO_4$ which again confirmed the presence of Fe deficiency. Iron deficiency was further evaluated by analyzing plant and soil, and estimating chlorophyll content of leaves. Chlorotic leaves (TMV 2) contained generally more total Fe than non-chlorotic leaves (ICGV 86031). In contrast, non-chlorotic leaves contained more extractable Fe and chlorophyll than chlorotic leaves (Table 6). Hence, it is evident that the estimation of total Fe content in leaves could not reliably be related to the occurrence of Fe chlorosis. Extractable Fe and chlorophyll content in fresh leaves gave a better indication of Fe status than total Fe content (Table 6). Several authors have mentioned that analysis of leaf total Fe did not provide a proper diagnosis of Fe deficiency, because in many cases Fe deficiency symptoms are caused by inactivation of Fe in plant tissue and not from inadequate Fe uptake by leaves (Jones, 1972; Chen and Barak, 1982; Katyal and Sharma, 1980). Thus, total leaf Fe content is not a satisfactory index of Fe status (Chattopadhyay *et al.*, 1989; Mehrotra and Gupta, 1990). Extractable leaf Fe content was inversely related to the degree of Fe chlorosis in groundnut (Rao, 1982; Parkpian *et al.*, 1986). Therefore, estimation of extractable Fe content in fresh plant material appears to be the most satisfactory measure of plant Fe status. Similarly, leaf chlorophyll content is related to the degree of chlorosis with significantly more chlorophyll in Fe-tolerant ICGV 86031 than Fe-susceptible TMV 2 and ICGS 11 (Table 6). These results suggest that leaf chlorophyll can be used as an alternative indicator of Fe status in groundnut.

The experimental soil was alkaline (pH 8.5), rich in lime content (10.7%) and DTPA extractable Fe (6.9 ppm) (Table 4a). In addition, irrigation water was rich in bicarbonate

content (6.76 meq/l) and had a high electrical conductivity (2 mmho cm^{-1}) (Table 4b). All these factors will contribute to Fe chlorosis.

A visual chlorosis rating (VCR) system (on 1-5 scale) suggested by Potdar and Anders (1993) was used in this study for measuring the severity of Fe chlorosis. This VCR system appeared to be a rapid, inexpensive, and effective tool under field conditions. Moderate to severe Fe chlorosis occurred in both TMV 2 and ICGS 11 (Table 6 and Fig. 16), whereas ICGV 86031 remained green throughout its growth (Fig. 16).

Growth analysis results revealed significant differences in growth and drymatter production among the genotypes (Tables 7 to 11). ICGV 86031 had more plant height, leaf area, and accumulated dry matter in leaves, stem, and root than TMV 2 or ICGS 11. This improved growth and higher dry matter production resulted in higher haulm yield (4.37 t ha^{-1}) in ICGV 86031 (Fig. 31). Similarly, ICGV 86031 produced higher number of pods $plant^{-1}$ than TMV 2 or ICGS 11. However, its pod dry weights, test weight, and harvest index were inferior to ICGS 11. This resulted in nonsignificant differences in dry pod yields between ICGS 11 and ICGV 86031. TMV 2 yielded poorly (dry haulm and pod yields) because of its poor growth and dry matter production. This poor growth and yield in TMV 2 were mainly related to its high susceptibility to Fe chlorosis. Similar results were found in a on-station study at ICRISAT (RMP Annual Report, 1993). Although ICGS 11 was also susceptible to Fe chlorosis, it yielded better than TMV 2 due to its better ability to convert dry matter into pods. Other studies also reported TMV 2 and ICGS 11 as susceptible to Fe chlorosis (Singh and Vidya Chaudhari, 1991; Reddy *et al.*, 1993; RMP Annual Report, 1993). All legumes including groundnut possess a specific mechanism

which allows them to absorb Fe by reducing rhizosphere pH (Romheld and Marschner, 1986; Marschner *et al.*, 1986). Such mechanism might have helped ICGV 86031 utilize Fe more efficiently than TMV2 or ICGS 11.

Genotypes differed significantly in their leaf and stem nutrient concentrations (Table 15 and 16). ICGS 11 contained a relatively higher concentration of nitrogen in leaves and stem. Whereas, TMV 2 was rich in phosphorus, calcium and magnesium concentrations in the leaves and stem (Table 15). In contrast, ICGV 86031 contained relatively high potassium concentration in the leaves and stem. These differences in nutrient concentrations may be attributed to genotype physiological differences in rooting systems and uptake patterns. High leaf concentration of phosphorus, calcium and magnesium might lead to inactivation of Fe in the plant systems of TMV 2 and ICGS 11. The role of these elements in inactivating Fe in plant system has been reported by Brown *et al.* (1959); Brown (1961); Wallace, *et al.* (1976a). High leaf and stem potassium concentrations might have resulted in improved Fe utilization by ICGV 86031. High potassium concentration in plant tissues is known to enhance Fe efficiency (Hughes *et al.*, 1992).

ICGS 11 contained a relatively higher concentrations of most micronutrient (Fe, Zn, Cu, and Mn) than ICGV 86031 and TMV 2. However, these high Fe concentrations were not associated with the occurrence of Fe chlorosis. Uptake of most macro and micro nutrients was higher in ICGV 86031 than in TMV 2 or ICGS 11 (Tables 17 and 18). These differences in nutrient uptake were due to different dry matter production in these genotypes.

ICGV 86031 was rich in oil content, but contained lower protein than TMV 2. While, ICGV 11 was intermediate for these qualitative characters.

Overall growth and yield performance of ICGV 86031 and ICGS 11 was better than TMV 2 which also gave higher net monetary returns and benefit/cost ratio (Table 21). However, ICGV 86031 was found highly tolerant to Fe chlorosis. Thus use of Fe-tolerant genotypes appears to be a promising solution to this nutrient disorder. However, the mechanisms for such high Fe-tolerance in ICGV 86031 are not known.

Fertilizer practices

The three fertilizer practices viz., no fertilizer control, farmer fertilizer practice (125 kg N + 200 kg P_2O_5 ha^{-1}), and recommended fertilizer practice (20:50:30 kg ha^{-1}) did not significantly affect Fe chlorosis. This was also reflected in leaf total Fe, extractable Fe, and chlorophyll content (Table 6).

Similarly, there was no significant effect of different fertilizer practices on the growth, yield and various yield attributes. Soil of the experimental site was rich in available N and P, exchangeable K, zinc and total Fe. This high soil fertility might have resulted in the nonsignificant effects of different fertilizers practices. However, high soil P (Wallace and Lunt, 1980) and NO_3-N (Chen and Barak, 1982) are known to induce Fe chlorosis in plants. Fertilizer practices did not significantly influence plant nutrient concentrations and their uptake except for N and P, where, farmer fertilizer practice had a relatively higher concentrations and uptake of N and P. Most growth and yield

parameters were not significantly influenced by different fertilizer practices. However, oil content was significantly improved by the recommended fertilizer practice.

Economic analysis of different fertilizer practices revealed that net returns obtained from recommended fertilizer practice and no fertilizer control were significantly higher than farmers fertilizer practices. No fertilizer control gave the highest B/C ratio (1.34) and the lowest (0.28) was obtained in farmer fertilizer practice.

These results suggest that application of such high fertilizer doses is not necessary, and farmers need to be made aware of the advantages of low fertilizer doses on groundnut in these areas.

Foliar Fe sprays

Foliar Fe sprays were found to be most effective in the correction of Fe chlorosis and significantly improved the groundnut growth and productivity (Tables 7 to 14, Fig. 31). Foliar Fe sprays significantly increased chlorophyll and Fe content (extractable and total Fe) in groundnut leaves (Table 6). Such effects of Fe sprays in groundnut were found in several studies (Singh *et al.*, 1989; Singh and Devidayal, 1992; Potdar and Anders, 1993).

Foliar Fe sprays significantly increased leaf nitrogen concentration and Fe concentration in both leaves and stem. However, leaf manganese concentration was significantly reduced by Fe sprays. Zaharieva *et al.* (1988) reported that high plant Fe can hamper manganese uptake in groundnut grown on calcareous soil. Uptake of most nutrients was generally improved by foliar Fe sprays.

Foliar Fe sprays significantly increased pod dry yields by about 20% over the nonsprayed control. Such an improvement in groundnut dry pod yield due to Fe sprays have been observed in several studies (Singh *et al.*, 1990; Potdar and Anders, 1992, 93; Singh and Devidayal, 1992).

Economic analysis revealed that foliar iron sprays significantly increased the total gross and net returns and gave higher benefit/cost ratio (1.06) than the nonsprayed control. Foliar iron sprays alone resulted in a net benefit of Rs. 2316 over the nonsprayed control (Table 21).

It is evident from the present study that foliar Fe sprays (0.5% w/v) are effective for correction of Fe chlorosis and improving groundnut pod yields. However, use of Fe efficient genotypes such as ICGV 86031 appears to be a long-term solution for Fe chlorosis in groundnut. Fe chlorosis can cause pod yield loss upto 17% in susceptible genotypes (TMV 2 and ICGS 11). The approach of initial villages surveys followed by a diagnostic on-farm trial was effective for accurate diagnosis of the problem and development of suitable management strategies for Fe chlorosis in groundnut.

SUMMARY

CHAPTER VI

SUMMARY

Iron chlorosis is one of the major nutritional constraints to groundnut production in Rayalseema region of Andhra Pradesh. The major objective of this study was to integrate farmers' perceptions and management practices for Fe chlorosis with a follow-up on-farm study to evaluate key management practices viz., genotypes, fertilizer practices, and foliar Fe sprays for the correction of Fe chlorosis in groundnut.

Intensive surveys were conducted in two contrasting villages (Kottapeta and Pasupalla) in Kurnool district of Andhra Pradesh, where groundnut is predominantly grown and often suffers from Fe chlorosis. Farmers in each of these villages were first stratified by landholding into three groups (small, medium, and large), and then a total of 30 farmers (10 from each group) were randomly selected for detailed surveys. Data on farmers perceptions and management practices for Fe chlorosis were collected using interview schedule developed for this purpose. The main findings of the survey were:

Survey

i. Farmers' identified Fe chlorosis as one of the major production constraints to groundnut, and estimated yield losses between 20 to 40% due to Fe chlorosis.

ii. Farmers in these villages preferred deep Vertisols with medium to high fertility for groundnut production.

iii. TMV 2 is the predominant genotype in these areas and often suffers from Fe chlorosis.

iv. Groundnut is generally fertilized with high doses of nitrogenous fertilizers ranging from 100-200 kg N ha^{-1}, applied in 2 to 4 splits.

v. Iron chlorosis was more severe in Pasupalla than Kottapeta, and farmers related the incidence of Fe chlorosis to irrigation practices and/or waterlogging, along with soil characteristics.

vi. In these villages, Fe chlorosis mostly occurred in patches rather than uniform chlorosis throughout the field.

vii. Farmers perceived low soil fertility, high lime content and soil alkalinity, excess irrigation and/or waterlogging, and nitrogen deficiency as the main causes for Fe chlorosis.

viii. Farmers in these areas often mistook Fe chlorosis symptoms for nitrogen deficiency and responded with high doses of nitrogenous fertilizers.

ix. Results indicated that calcareous and alkaline soil characteristics, use of Fe inefficient genotype, mismanagement of irrigation water, use of high doses of nitrogen were the main causes for Fe chlorosis in groundnut in these areas.

x. These findings assisted in designing an on-farm trial which evaluated the role of Fe efficient genotype (ICGV 86031), different fertilizer practices, and foliar Fe sprays for correction of Fe chlorosis in groundnut.

The major findings of this on-farm trial were:

Field trial

i. Severe and uniform Fe chlorosis occurred as early as the seedling stage in TMV 2 and ICGS 11. Whereas, ICGV 86031 remained green throughout the crop growth. These chlorotic symptoms disappeared within 5 days after foliar sprays with $FeSO_4$ which confirmed the presence of Fe deficiency at the experimental site.

ii. Soil at the experimental site was alkaline and rich in lime and Fe content. In addition, the irrigation water was also rich in bicarbonate content and had high electrical conductivity. These factors are known to induce Fe deficiency in plants.

iii. Among various diagnostic techniques used, extractable Fe and chlorophyll content in young expanding leaves appeared to be a better indices for Fe status of groundnut than the total Fe content in leaves or soil.

iv. ICGV 86031 leaves contained higher concentration of extractable Fe and chlorophyll than TMV 2 and ICGS 11.

v. Visual chlorosis rating (VCR) system (on 1-5 scale) appeared to be a rapid, inexpensive, and effective tool for measuring severity of Fe chlorosis in groundnut under field conditions.

vi. TMV 2 and ICGS 11 were susceptible to Fe chlorosis resulting in poor growth and dry matter production than ICGV 86031. As a result, ICGV 86031 produced higher haulm and pod yields and also gave higher

monetary returns than TMV 2. Whereas ICGS 11, though susceptible to Fe chlorosis, yielded better than TMV 2.

vii. Results of the nutrient analysis of leaves and stem tissues indicated that susceptible genotypes TMV 2 and ICGS 11 contained higher concentration of phosphorus, calcium and magnesium than ICGV 86031. These nutrients are known to inactivate Fe in plant tissues resulting Fe chlorosis.

viii. Therefore, use of Fe tolerant genotypes such as ICGV 86031 appears to be a promising solution for Fe chlorosis.

ix. Different fertilizer practices did not significantly influence the growth and productivity of groundnut. These results suggest that farmers need to be demonstrated the value of low fertilizer use in groundnut.

x. Foliar Fe sprays (0.5%) were effective in correction of Fe chlorosis and improved groundnut pod yields by about 20% over nonsprayed control. It was estimated that Fe chlorosis can cause pod yield losses upto 17% in groundnut.

xi. Foliar Fe sprays significantly increased net monetary returns and benefit/cost ratio over the nonsprayed control. By spending an additional amount of Rs. 245 ha^{-1} for foliar Fe sprays, net benefit of Rs. 2316 ha^{-1} was obtained.

xii. These results suggest that use of tolerant genotype such as ICGV 86031 or foliar Fe sprays in susceptible genotypes (TMV 2 and ICGS 11) as the possible management strategies for alleviation of Fe chlorosis in groundnut.

LITERATURE CITED

LITERATURE CITED

Adams F and Pearson R W 1967 Crop response to lime in the southern United /states and Puerto Rico. pp 161-206. *In* : Soil acidity and liming (ed. R W Pearson and F Adams). Monogr. 12. Am. Soc. Agron. Madison, Wisconsin, U.S.A.

Agrawala S C and Sharma C P 1979 Recognizing the micronutrient of crop plants on the basis of visible symptoms and plant analysis. Department of Botany, Lucknow University, Lucknow, India. p 72.

Atkas M and Vanegmond F 1979 Effect of nitrate nutrition on iron utilization by an Fe efficient and Fe inefficient soybean cultivar. Plant and Soil. 51:257-274.

Allison I E 1965 Organic carbon. pp 1367-1378 *In* : "Methods of Soil Analysis". Part II. (ed. C A Black) Am. Soc. Agron. Madison, Wisconsin, U.S.A.

Annual Report 1993 Resource Management Program ICRISAT, Patancheru, Hyderabad.

Ashalatha M 1991 Differential response of groundnut genotypes to iron stress MSc(Ag) Thesis submitted to Andhra Pradesh Agricultural University, Hyderabad.

Awad F, Romheld V and Marschner H 1988 Mobilization of ferric iron from a calcareous soil by plant borne chelators (phytosiderophores). J. Plant Nutr. 11:701-713.

Azarbadi S and Marschner H 1979 Role of rhizosphere in utilization of inorganic iron III compounds by corn plants. Z. Pflanzenernaehr. Bodenkd. 142:751-764.

Barak P and Chen Y 1984 The effect of potassium on iron chlorosis in calcareous soils. J. Plant Nutr. 7:125-133.

Basu M S and Reddy P S 1989 Technology for increasing groundnut production. National Research Center for Groundnut, Junagadh, Gujarat. I.C.A.R Publication.

Bhaskar P B 1990 Iron nutrition of groundnut in Alfisol Ph.D. Thesis submitted to Andhra Pradesh Agricultural University, Hyderabad.

Blenfait J 1983 Iron absorption in plants. Micronutrient News. A publication of micronutrient bureau, London. 4(2):3-5.

Bouyoucos G J 1962 Hydrometer method improved for making particle size soil analysis of soils. Agronomy Journal. 54:464-465.

Boxma R 1972 Bicarbonate is the most important soil factor in lime induced chlorosis in the Netherlands. Plant and Soil. 37:233-243.

Branston D and Jacobson L 1962 Iron transport in pea plants. Plant Physiol. 37:539-545.

Brown J C 1961 Iron chlorosis in plants. Advances in Agronomy 13:329-369.

Brown J C 1978 Mechanism of iron uptake by plants. Plant, Cell, Environ. 1:249-257.

Brown J C 1979 Differential use of Fe^{3+} and Fe^{2+} by oats. Agronomy Journal 71:89

Brown J C and Ambler J E 1970 Further characterization of iron uptake in two genotypes of corn. Proc. Soil. Sci. Soc. Am. 34(2):249-254.

Brown J C and Ambler J E 1974 Iron stress response to tomato (*Lycopersicum esculentum L.*) I. Sites of Fe reduction, absorption and transport. Plant Physiology 31:221-224.

Brown J C and Bell W D 1969 Iron uptake dependent upon genotype of corn. Proc. Soil. Sci. Soc. Am. 33:99-101.

Brown J C and Jones W E 1976 A technique to determine iron efficiency in plants. Soil Sci. Soc. Am. J. 40: 388-405.

Brown J C and Jones W E 1977 Fitting plants nutritionally to soils. II. Cotton. Agron. J. 69:405-409.

Brown J C and Jolley V D 1989 Plant metabolic responses to iron deficiency stress. Bioscience 39:546-551.

Brown J C, Tiffin L O, Homes R S, Spetch A W and Rehicky J W 1959 Internal inactivation of iron in soybean as affected by root growth medium. Soil Science 7:89-94.

Brown J C, Holmes R S and Tiffin L C 1961 Hypothesis concerning iron chlorosis. Soil Science Society of America Proceedings. 23(3):231-234.

Brown J C, Yomaguchi S and Diaz J 1965 Evidences for translocation of iron in plants. Plant Physiology. 40:35-38.

Bundy L G and Bremner J M 1973 Inhibition of nitrification in soils. Soil Sci. Soc. Amer. Proc. 37:396-398.

Burtch L M, Thorne D W and Wann F B 1948 The effect of light soil temperature, and soil moisture on lime induced chlorosis. Soil Sci. Soc. Am. Proc. 13:394-398.

Chaney R L 1984 Diagnostic practices to identify iron deficiency in higher plants. J. Plant Nutr. 7:47-67.

Chaney R L and Coulombe L 1982 Effect of phosphate on regulation of Fe stress response in soybean and peanut. J. Plant Nutr. 5:469-487.

Chattopadhyay A, Subramanyam K, Anwar M, Singh D V and Srivastava N K 1989 Nutrient composition and photosynthetic characters of chlorotic and normal plant of Japanese mint (*Mentha arvensis L.*). Plant Physiology and Biochemistry 16(2): 163-165.

Chen Y 1993 Correction of iron chlorosis In : Abstracts 7th International Symposium on Iron Nutrition and Interactions in Plants, 27 June - 2 July 1993. Zaragaza, Spain.

Chen Y and Barak P 1982 Iron nutrition of plants in calcareous soils. Adv.Agron. 35:217-240.

Chen Y, Naravot J and Barak P 1982 Remedy of lime induced chlorosis with iron enriched muck. J. Plant Nutr. 5(4-7):927-940.

Clark R B and Gross R D 1986 Plant genotype differences to iron. J. Plant Nutr. 9(3-7): 471-491.

Clarkson D T and Sanderson J 1978 Sites of absorption and translocation of iron in barley roots. Plant Phyiol. 61:731-736.

Coulombe B A, Chaney R L and Weibold W J 1984 Bicarbonate directly induce iron chlorosis in susceptible soybean cultivars. Soil Sci. Soc. Am. J. 48:1297-1301.

Cox F R and Kamprath E J 1972 pp 289-307 *In* : Micronutrients in Agriculture (ed. J J Mortvedt) SSAC, Madison, Wisconsin U.S.A.

Dahiya S S and Mehendra Singh 1976 Effect of salinity, alkalinity and iron application on the availability of Fe, Mn, P and Na in pea crop. Plant and Soil. 44:697-702.

Dekock P C 1955 Iron nutrition of plants at high pH. Soil Science. 79:167-176.

Dekock P C, Hall A and Mcdonald M 1960 A relation between the ratios of phosphorous to iron and potassium to calcium in mustard leaves. Plant and Soil 12:128-142.

Dilworth M J and Glenn A R 1984 How does a legume nodule work ?. Trends in Biochemical Sciences. 9:519-522.

*Djendor C 1972 The effect of iron deficiency on sunflower plant. Reve Roumaine de Biologie Botanique. 7(6):363-368.

Elliott G C and Lauchli A 1985 Phosphorus efficiency and phosphate-iron interaction in maize. Agron. J. 77:399-403.

Fehr W R 1984 Current practices for correction of iron deficiency in plant with emphasis on genetics. J. Plant Nutr. 7:347-354.

Field S P and Kameli J 1987 Food legumes for calcareous soils of Timor. pp 312-313. *In* : Food legume improvement for Asian farming systems (ed. E S Wallis and D E Byth) A.C.I.A.R Proceeding Series No. 18.

Francois L E and Goodin J R 1972 Interaction of temperature and salinity on beet germination. Agron. J. 64:272-273.

*Gris E 1844 Nouvelles experiencess surl' action de composes ferrugineux solubles applique a'la vegetation et special ement traitement de la chlorese et de la debilite des plantes. Comp. rend. acad. Sci. 19:1118-1119.

Hagstrom G R 1984 Current management practices for correcting iron deficiency in plant with emphasis on soil management. J. Plant Nutr. 7(1-5):23-46.

Haldar M and Mandal L N 1981 Effect of P and Zn on the growth and P, Zn, Cu, Fe and Mn nutrition of rice. Plant and Soil. 59:415-420.

Harley C P and Lindner R C 1945 Observed responses of apple and pear trees to some irrigation waters of north central Washington. Am. Proc. 24:361-364.

Hartzook A 1975 Lime induced iron chlorosis in groundnut: Treatment and Prevention. FAO Plant Protection Bull. 23:40-42.

Hauba V J G, Vanegmond F and Wittich E M 1971 Changes in production of organic nitrogen and carboxylate (C-A) in young sugar beet plants grown in nutrient solutions of different nitrogen composition. Neth. J. Agric.Sci. 19:39-47.

Hemantharajan A and Garg O K 1986 Introduction of nitrogen fixing nodules through iron and zinc fertilization in the non nodule forming French bean (*Phaseolus vulgaris L.*). J. Plant Nutr. 9:281-288.

Hiscox J D and Israelstam G F 1978 A method for the extraction of chlorophyll from leaf tissue without maceration. Can. J. Bot. 57:1332-1334.

Holmes R S and Brown J C 1955 Chelates as correctives for chlorosis. Soil Sci. 80:167-179.

Hughes D F, Jolley V D and Brown J C 1992 Role of potassium in the iron-stress response mechanisms of Strategy I and Strategy II plants. J. Plant Nutr. 15: 182-183.

ICRISAT PMD No 32 1990 Groundnut elite germplasm ICGV 86031

Inskeep W P and Bloom P R 1986 Effects of soil moisture on soil pCO_2, soil solution bicarbonate, and iron chlorosis in soybeans. Soil Sci. Soc. Am. J. 50:946-952.

Jackson M L 1967 Soil chemical analysis. Prentice hall of India. Pvt. Ltd. New Delhi.

Jacobson L 1945 Iron in the leaves and chloroplasts of some plants in relation to their chlorophyll content. Plant Physiol. 20:233-245.

Jacobson L 1951 Maintenance of iron supply in nutrient solutions by a single addition of ferric potassium ethylene diamine tetra-acetate. Plant Physiol. 26:411-413.

Jambunathan R, Madhusudhana Raju S, and Subhana P B 1985 Analysis of oil content of groundnut by Nuclear magnetic resonance spectrometry. J. Sci. Food Agri. 36:162-166.

Jolley V D, Brown T C and Hartzook A 1987 Field observation of iron chlorosis in peanuts as related to iron stress responses in solution culture. Agronomy abstracts pp 206.

Jolley V D, Brown J C, Blaylock M J and Camp S D 1988 A role for potassium in the use of iron by plants. J. Plant Nutr. 11:1159-1175.

Jones J B Jr 1972 Plant tissue analysis for micronutrients pp. 319-346 *In* : Micronutrients in Agriculture (ed. J J Mortvedt, P M Giodan, W L Lindsay). Soil Sci. Soc. Amer. Madison, Wisconsin, U.S.A.

*Juritz C F 1912 Agricultural Journal University of South Africa. 4:854-865.

Jurkevitch E, Hadar Y and Chen Y 1988 Involvement of bacterial siderophores in the remedy of lime induced chlorosis in peanut. Soil. Sc. Soc. Am.J. 52(4): 1032-1037.

Kannan S 1982 Genotypic differences in iron uptake, utilization in some crop cultivars. J. Plant Nutr. 5(4-7):531-542.

Kannan S 1984 Problems of iron deficiency in different crops plants in India : Causative factors and control measures. J. Plant Nutr. 7:187-200.

Kannan S 1988 Occurrence of iron deficiency in important crops in Maharashtra and Tamil Nadu States in India: a report. J. Plant. Nutr. 11(6-11):1285-1293.

Kannan S and Pandey D P 1982 Absorption and transport of iron in some crop cultivars. Journal of Plant Nutrition. 5:395-403.

Katyal J C and Randhawa N S 1983 Micronutrient fertilizer and plant nutrition FAO, Bull. No.7, Rome.

Katyal J C and Sharma B D 1980 A new technique of plant analysis to resolve iron chlorosis. Plant and Soil 55:105-119.

Keeney D R and Nelson D W 1982 Nitrogen-Inorganic forms. *In* : "Methods of Soil Analysis" Part II (ed. A L Page, R H Miller and D R Keeney) Agronomy 9:403-698. Am. Soc. Agron. Madison, Wisconsin, U.S.A.

Kovanir I, Hakerler H and Hofner W 1978 Causes of iron chlorosis in mandarins (*Citrus reticulata blanco*) in the Aegean area. Plant and soil 50:193-205.

Kumar V, Shrotriya G C, and Kaore S V 1990 Soil fertility and fertilizer use Vol iv. Indian Farmers Fertilizer Cooperative Ltd. Agric. Services Dept. Marketing Div. New Delhi.

Kumarohita K, Phetchawee S and Morakul P 1966 An investigation of the development of chlorosis in peanut grown on Rendzina soils of Thailand. pp 103-111 *In* : Ann. Rep. on Fertilizer Experiments and Soil Fertility Research. . Division Agric. Chemistry. Dept. Agric. Thailand.

Kuo S and Mikkelson D S 1981 Effect of P and Mn on growth response and uptake of Fe, Mn and P by sorghum. Plant Soil 62:15-22.

Landsberg E C 1986 Functions of rhizodermal transfer cells in Fe stress responses to Fe deficiency stress of mono - and dicotyledonous plant species. J. Plant Nutr. 3:579-591.

Lee D Y, Lin C H, Haung S P and Houng K N 1983 Effects of sulfur application to calcareous soils in Haulein area on the yields of peanuts. Soil and Fertilizer in Tiawan 12:35-43.

*Lindsay W L 1979 Chemical Equilibria in Soils. Wiley- Interscience, New York.

Lindsay W L 1984 Soil and plant relationships associated with iron deficiency with emphasis on nutrient interactions. J. Plant Nutr. 7(1-5):489-500.

Lindsay W L and Norvell W A 1978 Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Sci. Soc. Am. J. 42:421-428.

Mandal L N and Haldar H M 1980 Influence of phosphorus and zinc application on the availability of zinc, copper, iron, manganese and phosphorus in waterlogged rice soils. Soil Sci. 130:251-257.

Marschner H 1986 Mineral nutrition of higher plants. Academic Press Inc (London) Ltd. London N W 1 7 DX, England.

Marschner H, Romheld V and Kissel M 1986 Different strategies in higher plants in mobilization and uptake of iron. J. Plant Nutr. 9:695-713.

Mehrotra S C, Sharma C P and Agrawala S C 1988 Iron phosphorus interaction in chickpea genotypes that differ in tolerance to iron stress. pp 208. *In* : Abstracts of International Congress of Plant Physiology. New Delhi.

Mehrotra S C and Gupta P 1990 Screening of chickpea (*Cicer arietinum* L.) varieties under iron deficiency stress conditions using biochemical indicators. Indian Journal of Agricultural Sciences 60(8):566-568.

Mengel K and Kirkby E A 1979 Principle of plant nutrition II edition published by International Potash Institute, Berne, Switzerland, pp 211-240.

Mikkelsen R L and Behel A D 1988 Gelled fertilizers as slow-delayed release nutrient sources. Agron. Abstracts. p 303.

Miller G W, Pushnik J C and Welkie G W 1984 Iron chlorosis a world wide problem: The relation chlorophyll biosynthesis to iron . J. Plant. Nutr. 7:1-22.

Mino Y, Ishida T, Ota N, Inoe M, Nomutu K, Takemotu T, Tanaka H and Suginara Y 1983 Mugineic acid iron (III) complex and its structural analogous cobalt (III) complex characterization and implications for absorption and transport of iron in graminaceae plants. Journal of American Chemical Society. 105:4671-4676.

Monge E, Val J, Heras L and Abadia J 1987 Photosynthetic pigment showed composition of higher plants grown under iron stress. pp 1-204. *In* : Progress in photosynthesis research (ed. J J Biggeins) Vol. 4:20, Dordrecht, Netherlands).

Moraghan J T 1987 Effects of phosphorus and iron fertilizers on the growth of two soybean varieties at two soil temperatures. Plant Soil 104:121-127.

Moraghan J T and Mascagni H J 1991 Environmental and soil factors affecting micronutrient deficiencies and toxicities. pp 370-424. *In* : Micronutrients in agriculture, II ed. Soil Sci. Sco. Amer. Madison, Wisconsin, U.S.A.

Morris D R, Loeppert R H and Morre T J 1990 Indigenous soil factors influencing iron chlorosis of soybean in calcareous soils. Soil Science 54:1329-1336.

Mortvedt J J 1975 Iron chlorosis. Crop and Soil magazine Aug-Sept:10-13.

Mortvedt J J 1986 Iron sources and management practices for correcting iron chlorosis problems. J. Plant Nut. 9:961-974.

Mortvedt J J 1991 Correcting iron deficiency in annual and perennial plants: Present technology and future prospects. Plant and Soil 130:273-279.

Mortvedt J J and Giordano P M 1973 Grain sorghum response to iron in a ferrous sulfate - ammonium thiosulfate - ammonium polyphosphate suspension. Soil Sci. Soc. Amer. Proc. 37:951-955.

Nagaraj G 1987 Effect of foliar spray of micronutrients on yield and chemical composition of peanut in calcareous soils of Junagadh. Annals of Pl. Physiol. 1(2): 196-202.

Nambiar P T C 1990 Nitrogen nutrition of groundnut in Alfisols ICRISAT Information Bulletin no. 30.

Narayanan A and Reddy K B 1983 Effects of iron deficiency on the phytomass and inorganic composition of groundnut seedlings grown in solution culture. Journal of Plant Nutrition. 2:91-97.

O' Hara G W, Dilworth M J, Boonkerd N and Parkpian P 1988 Iron deficiency specifically limits nodule development in peanut inoculated with Bradyrhizobium sp. New Phytologist 108(1):51-57.

Olomu M O, Racz G J and Cho C M 1973 Effect of flooding on EC, pH and concentrations of Fe and Mn in several Manitoba soils. Soil Sci. Sco. Am. Proc. 30:82-86.

Olsen R V 1950 Effects of acidulations, iron oxide addition, and other soil treatments on sorghum chlorosis and iron absorption. Soil Sci. Soc. Amer. Proc. 15:97-101.

Olsen R V 1965 Iron. pp 963-973. *In* : Methods of Soil Analysis (ed C A Black), American Society of Agronomy and American Society for testing and materials, Madison, Wisconsin, U.S.A.

Olsen R A and Brown J C 1980 Factors related to iron uptake by dicotyledonous and monocotyledonous plants. pH and reductant. Journal of plant nutrition 2(6):629-645.

Olsen R V and Dean L A 1965 Phosphorus. *In* : "Methods of Soil Analysis" Part II (ed. C A Black) Am. Soc. Agron. Madison, Wisconsin, U.S.A.

Olsen S R and Watanabe F W 1979 Interaction of added gypsum in alkaline soils with uptake of iron, molybdenum, manganese and zinc by sorghum. Soil Sci. Soc. Am. J. 43:125-130.

Papastylianou I 1989 Effect of selected soil factors on chlorosis of peanut plants grown in calcareous soils in Cyprus. Plant and Soil. 117(2):291-294.

Parkpian P, Ratanarat S and Phetchawee S 1986 Diagnosis of iron chlorosis in soybean and peanut using orthophenanthroline method. pp 68-69 *In* : Ann. Report. Soil Sci. Division Dept of Agric. Thailand. April 1986,

Parkpian P, Bell R W, Ratanarat S and Phetchawee S 1988 Iron nutrition of field crops in black calcareous soils of Thailand: A review. J. Plant Nut. 11(6-11),1275-1284.

Parsa A A and Wallace A 1979 Organic solid wastes from urban environment as iron sources for sorghum. Plant Soil. 53:455-461.

Ponnamperuma F N 1972 The chemistry of submerged soils. Adv. Agron. 241:9-29.

Potdar M V and Anders M M 1992 Diagnosis and correction in iron chlorosis in groundnut. pp 462 *In* : Groundnut- A Global Perspective, Proc. International Workshop. (ed. S N Nigam) Nov 1991. Patancheru, A.P. India.

Potdar M V and Anders M M 1993 On-farm performance of groundnut genotypes under different land configurations and foliar iron sprays for the correction of iron chlorosis in Maharashtra state of India pp *In*: Abstracts of 7th International Symposium on Iron Nutrition and Interactions in Plants, 27 June - 2 July 1993. Zaragaza, Spain.

Price C A 1968 Iron compounds and plant nutrition. Ann. Rev. Pl. Physiol. 19: 239-248.

Pushnik J C, Miller G W and Manwaring J H 1984 The role of iron in Higher Plant Chlorophyll Biosynthesis, Maintenance and Chloroplast Biogenesis. J. Plant Nutr. 7(1-5):733-758.

Rao J K 1982 Investigations into nutritional dissorders causing chlorosis of groundnut (*Arachis hypogaea L.*) at ICRISAT center. MSc(Ag) Thesis submitted to Andhra Pradesh Agricultural University.

Rao J S P and Narayanan A 1990 Physiological aspects of iron deficiency in groundnut (*Arachis hypogaea L.*) and Blackgram (*Vigna mungo L.*). Madras Agric. J. 77(3-4):151-157.

Rao J S, Kumar D N R and Narayanan A 1988 Physiological aspects of Fe deficiency in certain grain legumes. pp.210. *In*: Abstracts of International Congress of Plant Physiology. New Delhi.

Rao J K, Sharawat K L and Burford J R 1987 Diagnosis of iron deficiency in groundnut, (*Arachis hypogaea L.*) Plant and Soil 97:353-359.

Ratanarat S, Parkpian P and Phetchawee S 1987 Iron deficiency in peanuts on black calcareous soils. *In*: Proc. Intern. Workshop on Food Legumes Improvement in Asian Farming Systems. 1-5 Sept. 1986, Khon Kaen, Thailand.

Razeto B 1982 Treatments for iron chlorosis in peach trees. J. Plant Nut. 5(4-7):917-922.

Reddy K B 1983 Developmental sequences of mineral nutrient deficiency symptoms and its influence on the pattern of iron uptake in groundnut. Ph.D. Thesis submitted to Andhra Pradesh Agricultural University, Hyderabad.

Reddy K B, Ashalatha M and Venkaiah K 1993 Differential responses of groundnut genotypes to iron-deficiency stress. J. Plant Nutr. 16(3):523-531.

Rediske J H and Biddulph O 1953 The absorption and translocation of iron. Plant Physiology. 28:577-593.

Reid P H and York E T 1958 Effect of nutrient deficiencies on growth and fruiting characteristics of peanuts in sand culture. Agronomy Journal. 50;63-70.

Riekels J W and Lingle J C 1966 Iron uptake and translocation by tomato plants as influenced by root temperature and manganese nutrition. Plant Physiol. 41: 1095-1101.

Romheld V and Marschner H 1981 Effect of Fe stress on utilization of Fe chelates by efficient and inefficient plant species. J Plant Nutr. 3:551-560.

Romheld V and Marschner H 1986 Mobilization of iron in the rhizosphere of different plant species. Adv. Plant Nutr. 2:155-204.

Romheld V, Marschner H and Kramer D 1982 Responses to Fe deficiency in roots of Fe efficient plants species. Journal of plant nutrition 5:489-498.

Ryan J and Stroehlein J L 1976 Copper industrial by products for improving iron deficient calcareous soils. Agron.J. 68:79-82.

Sarkar A N and Wyonjones R G 1982 Effect of rhizosphere pH on the availability and uptake of Fe, Mn, and Zn. Plant and Soil. 66:361-372.

Schwertmann U and Taylor R M 1977 Iron oxides. pp.145-180 *In* : Minerals in soil environments (ed. J B Dixin *et al.*) Soil Sci. Soc. Am. Madison, Wisconsin U.S.A.

Sekhon G S 1982 Some experiences in soil fertility management in India, pp 212-26. *In* : Whither Soil Research - Panel Discussion Papers. 12th International Congress Soil Science held at New Delhi during 8-16 February 1982.

Shaviv A and Hagin J 1987 Correction of lime induced chlorosis by application of iron and potassium sulphates. Fertilizer Research 13(2):161-167.

Shiv Raj A 1987 Extracts from the report on the nutritional disorders of crops in Andhra Pradesh. Personal Communication.

Sillanpaa M 1982 Micronutrients and nutrient status of soils, a global study, FAO, Soil Bull.No.48, Rome.

Simmons J N, Swindler R, Havzins M and Benedict H W 1963 Kinetic studies on regreening of Fe deficiency of soybeans. Plant Physiology 38:667-674.

Singh A L and Devi Dayal 1992 Foliar application of iron for recovering groundnut plants from lime induced iron deficiency chlorosis and accompanying losses in yields. J. Plant Nutr. 15(9):1421-1433.

Singh A L and Vidya Chaudhari 1991 Screening of groundnut (*Arachis hypogaea*) varieties tolerant to iron chlorosis. Indian J. Agri. Sci. 61(12):925-927.

Singh A L, Joshi Y C and Koradia V G 1987 Assessment of yield losses caused by iron chlorosis in groundnut. pp 20-21. *In* : Micronutrient stress in crop plants: Physiological and Genetical approaches to control them. Mahatma Phule Agricultural University, Rahuri, India.

Singh A L, Joshi Y C and Koradia V G 1989 Effect of micronutrient in combinations with sulphur on groundnut (*Arachis hypogaea L.*) in calcareous soil. In: Proceedings of the International Congress of Plant Physiology. New Delhi, India Feb.15-20.

Singh A L, Joshi Y C, Vidya Choudhari and Zala P V 1990 Effect of different sources of iron and sulphur on leaf chlorosis nutrient uptake and yield of groundnut. Fert. Res. 24:81-92.

Singh U and Jambhunadhan R 1981 Relationship between non protein nitrogen and total nitrogen in chickpea (*Cicer arietinum* L.) seed. J. Agric. Food Chem. 29: 423-424.

Small H G and Ohlrogge A L 1973 Plant analysis as an aid in fertilizing soybean and peanuts. pp 315-327. *In* : Soil testing and Plant analysis (ed. L M Walsh and J D Beaton) Soil Science Society of America, Madison, Wisconsin.

Spiller S and Terry N 1980 Limiting factors in photosynthesis. 2. Iron stress diminishing photosynthesis units. Plant Physiology 65:121-125.

Sutaria G S and Patel M S 1987 Effect of phosphorus, sulphur, zinc and iron on yield and nutrient uptake (P,S, Zn and Fe) by groundnut grown on highly calcareous clay soils. Indian. J. Agril. Chem. 20(1):39-48.

Suwanarat C and Suwanarit A 1986 Soil fertility. pp. 45-97 *In* : Groundnut Improvement Project. (ed. A Waranyuwat) Research Reports for 1982-1985. Kasetsart Univ. Bangkok.

Swarup A 1982 Availability of iron, manganese, zinc, and phosphorus in submerged, sodic soils as affected by amendments during the growth period of rice crop. Plant Soil 66:37-43.

Takagi S 1976 Naturally occurring iron-chelating compounds in oat and rice washing I. Activity measurement and preliminary characterization. Soil Sci. Plant Nutr. 22: 423-433.

Takkar P M and Mehta S K 1986 All India coordinated scheme of micronutrients in soils and plants. 39 p *In* : 17th annual report 1983-84. Indian Council and Agriculture Research, New Delhi, India.

Technicon Industrial systems 1972 Technicon Autoanalyzer II manual. Industrial Method No. 218-72A. Technicon Industrial Systems Tarrytown, New York, 10591.

Terry N and Low G 1982 Leaf chlorophyll content and its relation to the intracellular localization of iron. J. Plant Nutr. 5:301-310.

Thomas J D and Mathers A C 1979 Manure and iron effects on sorghum growth on iron deficient soil. Agron.J. 71:792-794.

Tiffin L O 1966 Iron translocation 1. Plant culture exudate sampling, iron-citrate analysis. Plant Physiol. 41:510-514.

Tisdale S L, Nelson W L and Beaton J D 1985 Soil Fertility. Macm. Pub.Co. New York.

Vanegmond F and Aktas M 1977 Iron nutritional aspects of the ionic balance of plants. Plant and Soil 48:685-703.

Vlek P L G and Lindsay W 1978 Potential use of finely disintegrated iron pyrites in sodic and iron deficient soils. J. Environ, Qual. 7:111-114.

Vose P B 1982 Iron nutrition in plants : A world overview. J. Plant Nutr. 5(4-7): 233-249.

Wallace A 1991 Rational approaches to control of iron deficiency other than plant breeding and choice of resistant cultivars. Plant and Soil 130:281-288.

Wallace A and Lunt O A 1960 Iron chlorosis in horticultural plants, a review. Proc. Amer. Soc. Hort. Sci. 75:819-641.

Wallace A and Lunt O A 1980 Iron chlorosis in horticultural plants. Proc. Amer. Soc. Hort. Sci. 75;819-641.

Wallace A and Wallace G A 1983 Studies on use of DTPA and EDDHA chelates to supply micronutrients to plants in soils including simulated drip irrigation. J. Plant Nutr. 6:457-460.

Wallace A and Wallace G A 1986 Ornamental plants most likely to be killed by iron deficiency and some control measures. J. Plant Nutr. 9:1009-1014.

Wallace A and Wallace G A 1992 Some of the problems concerning iron nutrition of plants after four decades of synthetic chelating agents. J. Plant Nutr. 15(10); 1487-1508.

Wallace A, Mueller R T, Lunt O A, Ashcroft R T and Shannon L M 1955 Comparisons of five chelating agents in soils, in nutrient solutions, and in plant responses. Soil Sci. 80:101-108.

Wallace A, Mueller R T, Patel P M and Soufi S M 1976 Use of waste pyrites form mine operations on highly calcareous soils. Commun. Soil Sci. Plant. Anal. 7(1): 57-60.

Wallace A, Romney E M and Alexander G W 1976a Lime induced chlorosis caused by excess irrigation water. Commun, Soil Sci. Plant Anal. 7:47-49.

Wallace A, Patel P M, Mueller R T and Cha J W 1976b Monocot-dicot variability in response to an iron oxide- metallic iron source. Commun. Soil. Sci. Plant Anal. 7(1):77-88.

Wallace A, Wood R A and Soufi S M 1976c Cation-anion balance in lime induced chlorosis. Commu. Soil Sci. Plant Anal. 7:15-26.

Wallihan E F and Garber M J 1968 Iron uptake by two citrus root stock species in relation to soil moisture and $CaCO_3$. Agron. J. 60 (1):50-52.

Wutscher H K, Olson E O and Shull A V 1970 Leaf nutrient levels, chlorosis and growth on calcareous soils. J. Am. Soc. Hort. Sci. 95(3):259-261.

Yen P Y, Inskeep W P and Westerman R L 1988 Effect of soil moisture and phosphorus fertilization on iron chlorosis of sorghum. J. Plant Nutr. 11:1517-1531.

Young P A 1967 Peanut chlorosis due to iron deficiency. Plant Disease Reporter. 51(6):464-467.

Zaharieva T and Romheld V 1991 Factors affecting cation- anion uptake balance and iron acquisition in peanut plants. Plant and Soil. 130(1-2):81-86.

Zaharieva T, Kasabov D and Romheld V 1988 Response of peanuts to iron - manganese interaction in calcareous soil. J. Plant Nutr. 11:1015-1024.

*** Originals not seen.**

APPENDIX

APPENDIX I

SURVEY OF IRON CHLOROSIS IN GROUNDNUT

Sr.No. : **Farmer category : Small / Medium / Large**

I. LOCATION:

Village : Mandal : District :

Farmers name :

Home address :

II. FARMER RESOURCES:

1. Land holding (ha):

Particulars	Rainfed	Irrigated	Total
Owned			
Leased in			
Leased out			
Total			

2. Soil Type : Vertisol / Alfisol / Mixed

Soil depth : Shallow / Deep

Fertility : Low / Medium / High

3. Water source and quality:

Source	Quality	Area covered (ha)
Well	Saline	
River	Poor	
Canal	Medium	
Others	Good	
	Total	

III. CROP MANAGEMENT PRACTICES:

1. Have you ever planted groundnut ? Yes / No

   If yes, when first planted ? year:_____

2. Are you regularly cultivating groundnut ? Yes / No

   If no, why ?_____

   _____

   If yes, why ? _____

   _____

   Area under groundnut cultivation (ha) during last three years.

Year	Kharif	Yield	Rabi	Yield	Summer	Yield
1992-93						
1991-92						
1990-91						

3. What cultivars did you plant ?

   Local : Improved:

4. Where did you obtain the seed from ?

   Government source / Local market / Other farmers / Own seed / Any other source

5. Did you give seed treatment ? Yes / No
   If no , why ?

6. What crop rotation do you follow in your farm ?

	Kharif	Rabi	Summer
a.			
b.			

7. When do you commonly plant groundnut ?.

Kharif : Rabi : Both seasons :

8. What fertilizers (bags/acre) did you apply to groundnut ?

1. Basal

Type	Source	Amount (kg)	Method
Nitrogen			
Phosphorus			
Potassium			
Other			

2. Top dressing

Type	Time	Source	Amount (kg)	Method
Nitrogen				
Phosphorus				
Potassium				
Other				

9. What method of irrigation and how frequently do you irrigate groundnut crop ?

Flooding : Strip :

Season	Method of irrigation	Frequency
Kharif		
Rabi		
Summer		

10. Are you regularly using canal irrigation ? Yes / No

If yes, when did you first use (year) canal irrigation on your farm ?

11. How frequently and at what rate the canal water is available for irrigating your groundnut crop ?

Kharif:

Rabi :

Summer:

12. Were herbicide sprays used to control weeds ?

Chemical	rate	When	Purpose

13. Were fungicidal sprays used ?

Chemical	rate	When	Purpose

14. Were pesticidal sprays used ?

Chemical	rate	When	Purpose

15. Did you receive any subsidies ?

What	When	How much

16 What are the major production constraints to groundnut production ?

Pests : Diseases : Nutrient disorders :

Drought : Others:

17. Was groundnut plant healthy, if not describe which part was affected and how did it look like ?

18. Did your groundnut plant look like these plants (show the photographs of iron chlorotic plants). Yes / No

IV PERCEPTION OF IRON CHLOROSIS

1. What did you thought it was (local name) ?

2. Was this a serious problem ? Yes / No

3. If yes, which season it was severe

   Kharif : Rabi : Both :

4. Were iron chlorotic plants distributed in one area of the field or throughout the field ?

   Patches : Uniform :

5. Was there any yield reduction due this problem ? If yes approximately how much ?.

6. What factors do you perceive causing this problem ?

   Soil : Climatic : Genotypes :

   Irrigation : Fertilizer practice : Others :

7. Did you apply any treatments to these plants / areas ?

What	rate	When	Was treatment effective

8. What are the general management practices you adopt to the effected crop ?

   Nitrogen application : Zinc application :

   Pesticide sprays : Irrigation management : Iron application :

   Other practices : No management practices :

9. What are the other crops effected by this problem ?

10. Did you seek help from anyone to solve these problems ?

    Agril. Dept. / T.V./ Radio / Literature / Others

11. Did you get any advice on iron chlorosis prior to planting of groundnut ? Yes /No
    If yes, what precautions did you take ?

V. HISTORICAL:

1. What was the crop you were growing prior to groundnut ?

2. Which area did you first select to grow groundnut ?

3. How did you manage this crop first ?

4. What problems did your crop have ?

5. What is the average yield of groundnut you obtained ?

6. How has your management practices changed between then and now with respect to fertilizer, irrigation, cultivar, land preparation, etc.. ?

7. What productions problems did you have in previous crops of groundnut ?

8. When did you first see these problems ?

9. Did your crop suffer with this problem before ? (Iron chlorosis)

10. Has it become worse overtime ?

11. Was this specific to :

Soil :	Season :
Source of irrigation :	Land forming :
Varieties :	Others :

12. Do other people have the same problem ?

13. What management practices did they follow ?

14. Was there any yield reduction due to this problem ?

15. Have you ever tried to solve this problem ? Yes / No
If Yes what did you do ?

16. Other details which he is interested to give .

VI. FUTURE :

1. Will you grow groundnut next season ? Yes / No

2. How you will change your management from the last season ?