EFFECT OF SOIL AND FOLIAR APPLICATION OF IRON ON NUTRIENT AVAILABILITY, UPTAKE, YIELD AND QUALITY OF SOYBEAN (*Glycine max.* L.)

by

Mr. Raj Kumar Meena
(Reg. No. K-17/111)

DIVISION OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

**RAJARSHEE CHHATRAPATI SHAHU MAHARAJ
COLLEGE OF AGRICULTURE, KOLHAPUR
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RAHURI-413722, DIST-AHMEDNAGAR
MAHARASHTRA, INDIA**

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A Thesis submitted to the

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MAHARASHTRA, INDIA.

In partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

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2019

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
there of has not been submitted
by me or other person to any
other University or Institute
for a Degree or
Diploma

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Date : / / 2019

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CERTIFICATE

This is to certify that the thesis entitled,**"EFFECT OF SOIL AND FOLIAR APPLICATION OF IRON ON NUTRIENT AVAILABILITY, UPTAKE, YIELD AND QUALITY OF SOYBEAN (*Glycine max.* L.)"** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) in partial fulfilment of the requirement for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY**, embodies the result of a piece of bonafide research work carried out by **Mr. RAJ KUMAR MEENA** under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

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

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Place : Kolhapur (G. G. Khot)

Date : / / 2019

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Place: Kolhapur

Date : / / 2019 (R. K. Meena)

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ABBREVIATIONS

@	:	At the rate of
^oC	:	Degree celcius
%	:	Per cent
B:C ratio	:	Benefit cost ratio
A.O.A.C	:	Association of official analytical chemists
AAS		Atomic absorption spectrophotometry
Ca	:	Calcium
CD	:	Critical difference
cm	:	Centimeter
CCE	:	Calcium carbonate equivalent
DTPA	:	Diethylene triamine penta-acetic acid
DAS	:	Days after sowing
EC	:	Electric conductivity
et al.	:	And other (et alli)
etc.	:	Et cetera
Fe	:	Iron
FYM	:	Farm yard manure
$FeSO_4$	:	Ferrous sulphate
Fig.	:	Figure
g	:	Gram
GRDF	:	General recommended dose of fertilizer
ha^{-1}	:	Per hectare
HNO_3	:	Nitric acid
H_2O_2	:	Hydrogen peroxide
H_2SO_4	:	Sulphuric acid
i.e	:	That is (id est)
K	:	Potassium
kg	:	Kilogram
$KMnO_4$	:	Potassium permanganate
KDS	:	Kasbe Digraj soybean
kg ha^{-1}	:	Kilogram per hectare

m	:	Meter
M	:	Molar
mL	:	Milli litre
mm	:	Milli meter
MOP	:	Murate of potash
Mn	:	Manganese
M.P.	:	Madhya Pradesh
N	:	Nitrogen
$NaHCO_3$	:	Sodium bicarbonate
NH_4OAC	:	Ammonium acetate
NS	:	Non-significant
O.C.		Organic carbon
P	:	Phosphorus
pp.	:	Particular page
ppm		Parts per million
PSB	:	Phosphate solubilizing bacteria
q ha^{-1}	:	Quintal per hectare
RD	:	Recommended dose
S	:	Sulphur
SE	:	Standard error
S.Em.	:	Standard error mean
SSP	:	Single super phosphate
T	:	Tonnes
t ha^{-1}	:	Tonne (s) per hectare
TEA	:	Tri ethanol amine
viz.	:	Namely (videlicent)
IUE	:	Iron use efficiency
Zn	:	Zinc

ABSTRACT

EFFECT OF SOIL AND FOLIAR APPLICATION OF IRON ON NUTRIENT AVAILABILITY, UPTAKE, YIELD AND QUALITY OF SOYBEAN (*GLYCINE MAX*. L.)

by

Raj Kumar Meena

A candidate for the degree

of

MASTER OF SCIENCE (AGRICULTURE)
2019

Research Guide : Dr. B.M. Kamble

Division : Soil Science and Agricultural Chemistry

The experiment on effect of soil and foliar application of iron on nutrient availability, uptake, yield and quality of soybean (*Glycine max*.L.) was carried out at Agricultural Research Station, Kasbe Digraj, Dist: Sangli (MS) during *kharif* 2018. The experimental soil was alkaline, calcareous, clay in texture, low in available nitrogen, phosphorus, very high in available potassium and deficient in iron. The experiment was laid out in randomized block design with eight treatments and three replications. The treatment consist of T_1- absolute control, T_2- general recommended dose of fertilizer (GRDF), T_3- GRDF + soil application of $FeSO_4$ @ 10 kg ha^{-1}, T_4- GRDF + soil application of $FeSO_4$ @ 20 kg ha^{-1}, T_5- GRDF + $FeSO_4$ @ 10 kg ha^{-1} + cow dung slurry @ 500 litre ha^{-1}, T_6- GRDF + two foliar sprays of chelated Fe @ 0.2 per cent at 30 and 50 days after sowing (DAS), T_7- GRDF + soil application of $FeSO_4$ @ 10 kg ha^{-1} + two foliar sprays of chelated Fe @ 0.2 per cent at 30 and 50 DAS and T_8- GRDF + soil application of $FeSO_4$ @ 20 kg ha^{-1} + two foliar sprays of chelated Fe @ 0.2 per cent at 30 and 50 DAS. The general recommended dose of fertilizer (GRDF) for soybean was 50:75:45 $N:P_2O_5:K_2O$ kg ha^{-1} + 10 t FYM ha^{-1}.

The results revealed that the growth parameters of soybean *viz;* chlorophyll content, average number of days to 50 per cent flowering, plant height, number of branches per plant, number of pods per plant and effective root nodules per plant were significantly increased due to soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent at 30 and 50 days after sowing. The soil application of $FeSO_4$ @ 10 or 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent at 30 and 50 days after sowing enhanced growth of soybean as compare to only soil application or foliar spray of iron.

The significantly the highest grain and straw yield (24.93 q ha^{-1} and 37.79 q ha^{-1}) was obtained in T_8 over the rest of treatments. The per cent increasing in grain yield by treatment T_8 of soybean was 14 per cent over GRDF treatment and 81 per cent over the control, respectively. The T_8 was at par with T_7 (23.24 q ha^{-1}) and T_4 (23.14 q ha^{-1}) for grain yield of soybean. The quality parameters *viz;* oil and crude protein yield of soybean was enhanced due to soil applied of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent as compare to GRDF and absolute control.

Total N, P, K, Fe, Mn, Cu and Zn uptake of soybean were noticed significantly higher in treatment receiving $FeSO_4$ @ 20 kg ha^{-1} along with foliar sprays which is equivalent with $FeSO_4$ @ 10 kg ha^{-1} along with foliar sprays. The soil available N, P, DTPA Fe contents were affected significantly, however, available potassium, DTPA Zn, Cu and Mn content were found non-significant effect due to soil application and foliar spray of Fe treatments. The improvement in soil Fe content was observed above critical limit (4.5 mg kg^{-1}) at harvest stage in treatments receiving GRDF along with Fe application over initial DTPA iron content (4.05 mg kg^{-1}). Soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent at 30 and 50 days gave higher iron use efficiency over to GRDF. The more net returns from soybean was received in basal application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent at 30 and 50 days after sowing.

It is concluded from the study that the application of 50:75:45 $N:P_2O_5:K_2O$ kg ha^{-1} + 10 t FYM ha^{-1} and soil application of $FeSO_4$ @ 20 kg ha^{-1} alongwith two foliar sprays of chelated Fe @ 0.2 per cent at 30 and 50 DAS to soybean in iron deficient soil recorded higher growth parameters, yield, quality parameters, nutrient uptake and net monetary returns and B:C ratio. The residual soil fertility was improved in treatments received GRDF alongwith Fe as compare to initial soil fertility status.

1 INTRODUCTION

Soybean (*Glycine max* L.) is leguminous crop and it belongs to family papillionaceae, sub family of leguminoaceae, originally a crop of China. Soybean is cultivated for more than 3000 years in south eastern Asia (Dwevedi and Kayastha, 2011). Soybean stands first in the world as edible oil and occupies important place in the economy. Globally legumes play a vital role in human nutrition as these are rich sources of protein, calories, certain minerals and vitamins. Among legumes, soybean is the largest source of protein and vegetable oil with poly-unsaturated fatty acids specially Omega 6 and Omega 3 (Chauhan *et al.* 1988). Soybean has emerged as a potential oilseed crop and has brought perceptible change in the economy of the farmers in India. This crop is also a richest and cheapest source of best quality protein (40%) and fat (20%). Since 1980 onward, many varieties were developed in different parts of the country, which have different maturity and yield potentials.

Soybean is cultivated on 124 million ha area in the world. India ranks 5th in area and production after USA, Brazil, China and Argentina. All world estimated area and production of soybean in *Kharif*- 2017 was 10.60 million ha and 8.00 million MT respectively. In India area, production and productivity of soybean during 2017 was 101.5 lakh ha, 91.4 lakh million tonnes and 900 kg ha^{-1} respectively however in Maharashtra area, production and productivity of soybean during 2017 was 34.4 lakh ha, 31.8 lakh million tonnes and 925 kg ha^{-1}, respectively, where as in western Maharashtra the area under soybean was 12.61 lakh ha with production of 12.10 lakh MT and productivity was 959 kg ha^{-1} (Anonymous, SOPA 2017). Madhya Pradesh has substantial contribution, around 60 percent of total area and production of India and ranks first in area as well as in production. The estimated area and production during *Kharif 2018* in Madhya Pradesh was 54.00 million ha and 59.17 million MT respectively, so it is well known as "Soya State".

The area under soybean cultivation is increasing due to some reason such as soybean is short duration crop (90-110 days), good market price with its higher productivity as compared to other pulses. It can be processed easily for different products *viz*., soy cheese, soy milk, soy protein, soy yogurt, soybean oil, soy nut. Soybean also used for making the soy ink, soy paint and soy molasses. It can give a boost to the food-processing industry in rural areas of India. Soybean is miracle crop of 21st century which possesses potential to revolutionize Indian economy by correcting the health of human being and soil.

As an importance of soybean with limiting may factors for soybean production such as climatic and edaphic factors severely affect its production; According to Turner 1991, performance of this crop is highly affected by the availability of trace elements such as

Molybdenum and Iron. It has been also well reported that deficiency of micronutrients such as Fe, Mn and Zn affect the soybean production (Khudsar *et al*. 2008; Caliskan *et al*. 2008). Soybean productivity is also affected may be low availability of essential nutrients or imbalanced nutrition, this is one of the important constraints of soybean productivity in India. Hence a balanced nutrient application is must to increase the productivity of crop.

Among micronutrients, iron plays vital role in a structural component of porphyrin molecules, cytochromes, heams, hematin, ferrichrome and leghaemoglobin. These substances are involved in oxidation-reduction reactions in respiration and photosynthesis. It is also an important part of the enzymes, including amino levlinic acid synthetase and co-proporphyrin ogenoxidase, which is essential for nitrogen fixation in nitrogen fixing microorganisms. Iron in chloroplasts reflects the presence of cytochromes for performing various photosynthetic reduction processes and of ferrodoxin as an electron acceptor. The ferrodoxins are Fe-S proteins and are the first stable redox compound of the photosynthetic electron transport chain. Iron deficiency is usually observed in soybean grown in calcareous or alkaline soils. In calcareous soil, iron availability is restricted due to conversion of ferrous to ferric and showed deficiency of Fe manifest into yellowish inter-venal paling of younger leaves (commonly referred as iron chlorosis). Effective and judicious use of fertilizer in crops depends on the application of appropriate amount of fertilizer in balanced form. Therefore, nutrient management is of utmost importance in increasing the productivity of soybean. Micronutrients are increasingly being studied for their potential for increasing the yields of many crops. Since soybean yields have been somewhat stagnant, growers are looking for ways to boost yield to keep soybean profitable.

The use of fertilizers application strategies to achieve maximum yields and enhance nutrient use efficiency has been proposed for decades. With the increase in soybean yields due to important genetic improvements, demand for nutrient has also increased. It is likely that the increased utilization of reduced tillage systems and some soil conditions such as high soil pH found in large areas of the Great Plains may decrease the plant availability of some macro and micronutrients. This may be corrected through initially application at time of sowing and foliar fertilizer application of combination of starter and booster dose of fertilizer. Some soil conditions such as high soil pH and low organic matter may contribute to decrease the supply of micronutrients to crops. Increased nutrient demands from more intensive cropping practices and high yielding potential crops may also require additional micronutrient for optimum yields. Supplementary foliar application of N, P, K and micronutrients for deficient soils can help to enhance the crop yields under these conditions. Consequently, there is an increasing interest from producers about the potential benefits of foliar application of nutrients as compliment of their fertilization programs to maximize yields.

Keeping in view above facts, the present investigation entitled effect of soil and foliar application of iron on nutrient availability, uptake, yield and quality of soybean (*Glycine max.* L.)" has been under taken at Agricultural Research Station, Kasbe Digraj, with following objectives:

1. To study the effect of soil and foliar application of iron on chemical properties of soil and uptake of macro and micronutrients by *kharif* soybean.
2. To study the effect of soil and foliar application of iron on nutrient use efficiency, yield and quality parameters of soybean.

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2. REVIEW OF LITERATURE

The literature on work done pertaining to the "Effect of soil and foliar application of iron on nutrient availability, uptake, yield and quality of soybean" and related crops have been reviewed in this chapter. Review of literature regarding effect of different treatments is presented under the following suitable headings.

2.1 Effect of soil and foliar application of iron on growth parameters of soybean

2.2 Effect of soil and foliar application of iron on soil nutrient availability and nutrient uptake of soybean

2.3 Effect of soil and foliar application of iron on grain yield and straw yield parameters of soybean

2.4 Effect of soil and foliar application of iron on quality parameters of soybean

2.1 Effect of soil and foliar application of iron on growth parameters of soybean

Bhanavase *et al*. (1994) reported that the soil application of ferrous sulphate at 25 kg ha^{-1} to soybean crop increased nodulation, nodules dry weight per plant and dry matter accumulation as compared to control.

Shukla and Shukla (1994) noticed that the applied 25 and 50 kg $FeSO_4$ ha^{-1} to chickpea crop which resulted in increased number of nodules per plant, dry weight of root nodules, leghaemoglobin content of root nodules and rate of N_2 fixation as compared to control treatment.

Singh *et al*. (1998) reported that the soil application of 15 kg $FeSO_4$ ha^{-1} significantly increased grain and straw yield of mungbean by 9.78% and 11.81% over 0.1% $FeSO_4$ foliar treated plots. Further yield attributes were also increased significantly with 15 kg $FeSO_4$ ha^{-1} over foliar applied $FeSO_4$ and control treatment.

Mahriya and Meena (1997) conducted a field trial at Jobner (Rajasthan), and they concluded that all the growth characters *viz.*, plant height, number of branches per plant, dry matter production per meter row length were increased with the application of 4 kg Fe ha^{-1} in cowpea.

Agrawal *et al*. (2004) reported that the application 0.5 per cent foliar spray of $FeSO_4$ at 30, 40 and 50 days after transplanting to hybrid tomato (Cv. Avinash-2) was recorded maximum plant height, number of primary branches and number of leaves of hybrid tomato.

Wiersma (2005) noticed that the plants require a continuous supply of iron (Fe) to maintain proper growth and showed that the application of low rates of Fe chelates applied to reduce Fe deficiency in soybean *Glycine max* (L.).

Kumawat *et al*. (2006) conducted an experiment at Bikaner in mung bean and reported that the application of 25 kg $FeSO_4$ ha^{-1} gave the higher chlorophyll content in leaves, shoot weight and root nodules weight over control.

Kumar *et al*. (2009) conducted an experiment at Kanpur and reported that the branches per plant, number of pods per plant, number of grains per pod and test weight significantly increased with levels of Fe up to 10 kg Fe ha^{-1} over control in chickpea.

Basavaraj and Upper (2008) studied that the foliar and soil application of iron treatments resulted in increased pod, haulm yield, plant height, number of pods per plant and TDM (total dry matter) and lesser visual chlorosis rating (VCR) of groundnut over RDF.

Sharma *et al*. (2010) reported that the application of chelated Fe (1 or 2 kg ha^{-1}), all the yield contributing characteristics viz., number of pods per plant, number of pods per plant, number of seeds per pod and 100 seeds weight were significantly increased in pigeon pea crop.

Sintupachee *et al.* (2010) observed that the application of Fe-DTPA and Fe-EDDHA significantly increase growth of groundnut as compared to the control. The effectiveness of Fe-EDDHA in increasing growth of groundnut was higher than that of Fe-DTPA.

Ali *et al.* (2014) evaluated that the foliar applications of 0.5%, 1% and 1.5% solutions of $FeSO_4$ both at branching and flowering stages of mungbean. The results revealed that various $FeSO_4$ treatments increased growth components like plant height, number of pods bearing, branches per plant of mung bean.

Rajamani and Shanmugasundaram (2014) reported that the soil application of ferrous sulphate @ 50 kg ha^{-1} (+Fe) resulted in higher plant growth of black gram in all the genotypes as compared to control (-Fe).

Rawashdesh and Florin (2015) noticed that the foliar application of Iron, either single or along with other micronutrients can help achieve favorable results on growth parameters, yield components of wheat crop.

Bahure *et al*. (2016) reported that the recommended dose of fertilizer (30:60:30 kg NPK ha^{-1}) was applied at the time of sowing through urea, single super phosphate and muriate of potash. Application of RDF + $ZnSO_4$ 10 kg ha^{-1} + $FeSO_4$ 10 kg ha^{-1} + $MgSO_4$ 10 kg ha^{-1} + 1.5 per cent foliar application of $ZnSO_4$, $FeSO_4$ and $MgSO_4$ at 30 and 50 DAS recorded significantly higher growth and higher branches of soybean over the rest of the other treatments(control).

Al-Issawi and Mahdi (2016) noticed that effect of potassium and iron on growth of mungbean crop. It was concluded that nutrients must be added as a foliar application as they have progressive effect on growth as well as yield of mung bean.

Rui *et al.* (2016) evaluated that the effects of the chelated-Fe fertilizer (ethylene diamine tetra acetic acid-Fe; EDTA-Fe) fertilizer on the growth and development of peanut (*Arachis hypogaea* L). The results showed that increased root length, plant height, biomass, and SPAD values of peanut plants. The Fe contents in peanut plants with EDTA-Fe treatments were higher than the control.

Sale e*t al.* (2017) reported that the field experiment was conducted to the effect of micronutrients on growth of soybean with the treatments combination of recommended dose of fertilizer along with $FeSO_4$ (0.5%) + $ZnSO_4$ (0.5%) + Mo. The result revealed that the highest number of branches (16.83 plant^{-1}) observed in the treatment receiving combined application of zinc and iron with seed fortification of molybdenum. The higher values of chlorophyll content at 40 DAS (28.06 mg g^{-1}) of soybean was observed under treatment receiving foliar application of zinc and iron. The significantly highest number of nodules (44.66) was recorded in treatment application of seed fortification with MoO_4.

Kandoliya *et al.* (2018) noticed that the application of RDF + soil application of $ZnSO_4$ @ 10 kg ha^{-1} + $FeSO_4$ @ 20 kg ha^{-1} similarly, the yield attributes *viz*., plant height at 40 DAS, 70 DAS and at harvest; numbers of tillers at 45 DAS and at harvest and numbers of effective tillers at harvest of wheat crop were recorded significantly highest under treatment. Higher growth was observed in soil application of $FeSO_4$ and $ZnSO_4$ as compared to chelated Fe and Zn spray.

Sale *et al.* (2017) conducted afield experiment to assess the effect of micronutrients on growth of soybean grown under rainfed condition and they reported that the highest number of branches (16.83 plant^{-1}) observed in the treatment receiving combined application of zinc and iron with seed fortification of molybdenum. The higher number of (44.66) nodules were recorded in treatment seed fortification of molybdenum. The higher values of chlorophyll content at 20 DAS (19.90 mg g^{-1}), 60 DAS (18.14 mg g^{-1}) and 80 DAS (10.14 mg g^{-1}) of soybean was recorded with foliar application $FeSO_4$ spray (0.5%) + $ZnSO_4$ spray (0.5%) and along with seed fortification of molybdenum.

2.2 Effect of soil and foliar application of iron on soil nutrient availability and nutrient uptake of soybean.

Patel *et al.* (1993) conducted a field trial on calcareous soils of Gujarat revealed that foliar spray of 1 per cent $FeSO_4$ to groundnut leaves, increased concentration of Fe at all stages of crop growth.

Pande *et al.* (1993) studied the effect of iron on yield and uptake of nutrients in groundnut and the results revealed the foliar spray of 2.0 per cent $FeSO_4$ to groundnut increased uptake of N, K and Fe as compared to foliar spray of 0.5, 1.0 and 2.0 per cent $FeSO_4$ and soil applied $FeSO_4$ at 25 kg and 50 kg ha^{-1}.

Mundra and Bhati (1994) studied effect of iron, manganese and *Rhizobium* inoculation on growth, nodulation, iron: manganese ratio and protein content of cowpea and they reported that iron in both seed and straw increased with the application of ferrous sulphate in cowpea.

Mahriya and Meena (1997) conducted the field experiment to study the response of cowpea to phosphorus and iron on growth and quality of cowpea recorded that application of 4 kg ha^{-1} Fe significantly increased protein content of cowpea, but Fe content was increased significantly with the application of iron @ 6.0 kg ha^{-1} in cowpea seed over lower levels.

Chakerolhosseini *et al*. (2003) studied the response of soybean to phosphorus and iron in a calcareous soil and they reported that application of Fe up to 2.5 mg kg^{-1} increased dry matter of soybean but decreased it at higher rates, while the concentration and uptake of Fe increased by Fe application.

Kumawat *et al*. (2006) observed that the application of 25 kg $FeSO_4$ ha^{-1} to summer mungbean increased the activities of the catalase, aguaiacol peroxidise synthesis of chlorophyll and active Fe content of green leaves over lower doses of $FeSO_4$ and controlled treatment.

Patel *et al.* (2007) studied the effects of micronutrients with FYM on the yield of *kharif* groundnut (*Arachis hypogaea*) and their residual effect on succeeding wheat crop. Application of $FeSO_4$ and $ZnSO_4$ each at 25 kg ha^{-1} resulted in significantly higher DTPA-Fe and Zn control in post harvest soil and their uptake than other treatments.

Basavaraj and Upper (2008) conducted a field trial on Iron nutrition in groundnut (*Arachis hypogaea*) crop grown in calcareous Vertisols and results showed that the water soluble and DTPA-Fe concentration in soil were increased at flowering, pegging and pod formation stages of groundnut with soil application of $FeSO_4.7H_2O$ @ 25 kg per ha^{-1} and Fe-EDTA @ 6 kg per ha^{-1} over control.

Ravi *et al*. (2008) noticed that the treatment receiving 30 kg S ha^{-1} + Fe + Zn foliar spray recorded the highest micronutrients (zinc and iron) uptake of safflower as compared to other treatments.

Sintupachee *et al.* (2010) reported that the yield of groundnut grown on the soil amended with Fe-DTPA at the rate of 3 mg Fe kg^{-1} soil were similar to those of groundnut grown on the soil amended with Fe-EDDHA either at the rate of 1 mg Fe kg^{-1} soil or 3 mg Fe kg^{-1} soil. Application of Fe-EDDHA significantly increased total Fe uptake of groundnut as compared to that of control. The effectiveness of Fe-EDDHA in increasing availability of Fe to groundnut was higher than that of Fe-DTPA.

Magdi *et al.* (2011) observed that on cowpea a vital effect of macro and micronutrients on soil fertility. Meanwhile, less increase in soil available micronutrients (Fe, Mn and Zn). The treatment NPK+HS+BF gave the highest values 5.58, 3.04 and 1.50 mg kg^{-1} soil for Fe, Mn and Zn, respectively, compared with the other treatments.

Moosavi *et al.* (2011) noticed that the soil and foliar applications of Fe significantly increased shoot Fe concentration; however, foliar application was more effective. Foliar spray of 1 per cent Fe sulfate improved plant Fe content and had no effect on shoot dry matter yield

(SDMY). Soil addition of Fe decreased root Mn uptake probably due to the well-known antagonistic effect of Fe on Mn absorption; whereas, foliar Fe application had no negative effect on shoot Mn status.

Dalshad (2011) evaluated that the two different Fe sources (Fe-EDTA and Fe-EDDHA) were sprayed on the leaves and applied to the soil in levels were involved 0, 10, 20 and 30 mg l^{-1} both fertilizers were sprayed to leaves two times, the interval date was 20 days. The results significant of the Fe application on total dry matter of lentil.

Chaturvedi *et al.* (2012) concluded that the application of FYM and micronutrients viz., Fe and B along with 100 per cent NPK was essential for higher productivity and profitability of soybean as well as maintaining soil fertility.

Rehman and Shah (2018) studied that the effect of two levels each of Fe (2.5 and 5.0 kg ha^{-1}) and Mo (1.0 and 2.0 kg ha^{-1}) applied alone or in combination on nutrient uptake of pea. The required Fe and Mo as $[(NH_4)_6Mo_7O_{24}4H_2O]$ and $FeSO_4.7H_2O$ respectively were applied to soil followed by thorough mixing before sowing. Both Fe and Mo induced significant increases in nutrient uptake.

Poonia *et al.* (2018) reported that the application of $FeSO_4$ @ 25 kg ha^{-1} as basal + foliar spray of $FeSO_4$ @ 0.5 per cent at 45 and 75 DAS + citric acid @ 0.1 per cent at 45 and 75 DAS + 5 t FYM ha^{-1} significantly increased nitrogen and iron content, uptake of groundnut. Similarly, Application of $FeSO_4$ @ 25 kg ha^{-1} as basal + foliar spray of $FeSO_4$ @ 0.5 per cent at 45 and 75 DAS + citric acid @ 0.1 per cent at 45 and 75 DAS + 5 t FYM ha^{-1} significantly increased nitrogen and iron content and uptake in kernel over control.

Hanwate *et al.* (2018) studied that the effect of seed fortification with Mo and foliar application of Zn and Fe on uptake of nutrient at critical growth stages of soybean crop. The foliar application Zn and Fe @ of 0.5 per cent was undertaken at 30, 50 and 70 days after sowing. Micronutrient uptake was also noticed significant and maximum *i.e*. 162.91 g, 166.91 g and 177.41 g. Zn ha^{-1}, 398.85 g, 401.24 g and 402.39 g. Fe ha^{-1} and 189.57 g, 198.18 g and 203.15 g. Mo ha^{-1} at flowering pods formation and harvesting stage of soybean with use of treatment, except the Fe content was found maximum with the use of treatment which comprised of RDF along with foliar application of Fe and Zn.

Kandoliya and Kunjadia (2018) conducted field experiment to study the effect soil and foliar application of zinc and iron in wheat on micronutrients uptake in calcareous soil of Saurashtra region. The results showed that highest Fe content in grain and straw as well as uptake by straw and grain was observed in treatment of RDF + Spraying of chelated Fe @ 2.0 per cent. Higher nutrient uptake was observed in chelated Fe and Zn spray as compared to soil application of $FeSO_4$ and $ZnSO_4$. Application of chelated Fe and Zn spray increased the efficiency of fertilizers and improved wheat nutrient content including grain Zn and Fe.

2.3 Effect of soil and foliar application of iron on grain yield and straw yield parameter of soybean

Ravi *et al.* (2008) observed that the level of S and their combination with micronutrients had significant effect on the yield components and economics of the safflower. The treatment receiving 30 kg S ha^{-1} + Fe + Zn foliar spray recorded the highest growth and yield.

Sahu *et al.* (2008) reported that the application of $FeSO_4$ at 2 kg ha^{-1} along with biofertilizer inoculation gave the highest grain yield (1473 kg ha^{-1}) and straw yield (1473 kg ha^{-1} as compared to control in chickpea.

Mohammad *et al.* (2012) studied the effect of micronutrients foliar application on yield of safflower. The results indicated that micronutrient foliar spray had a significant effect on seed and biological yield and 1000 seed weight.

Abbas *et al.* (2009) noticed that the field experiments were conducted the micronutrient, *i.e.* Fe was applied @ 0, 4, 8, 12 and 16 kg ha^{-1} alone as well as combined in a same trial, in the form of Iron sulphate at the time of sowing. The best results were obtained when applied Fe @ 12 kg ha^{-1} with recommended NPK. Increasing rates of Fe dose up to 12 kg ha^{-1} increased wheat grain yield.

Kumar *et al.* (2009) conducted an experiment at Kanpur and results revealed that the application of 10 kg Fe ha^{-1} enhanced the grain yield of chickpea by 17.3 per cent over control.

Gohari and Niyaki (2010) reported that the experiment was conducted to study the effects of iron and nitrogen fertilizers on yield and yield components of peanut (*Arachis hypogaea* L.). the results showed that maximum pod and seed yield values of 2916 and 1828 kg ha^{-1}, respectively were recordedin the 4.5 g l^{-1} iron fertilizer treatment. results obtained in this study suggested 4.5 g l^{-1} iron (6 m^2) and 60 kg ha^{-1} nitrogen fertilizer resulted in the highest pod and seed yields 2314 and 1376 kg ha^{-1}, respectively.

Bybordi *et al.* (2010) noticed that the foliar and soil application of zinc and iron had the highest efficiency of seed production. The comparison of the various methods of fertilization showed that foliar application was more effective than soil application.

Sharma *et al*. (2010) reported that the application of chelated Fe (1 or 2 kg ha^{-1}), all the yield contributing characteristics as well as protein content in seed were significantly increased in pigeon pea crop.

Sintupacheek *et al.* (2010) studied that the effects of Fe-DTPA and Fe-EDDHA on yield of groundnut. the treatments consisted of the Control (without iron (Fe) fertilizer) and the application of iron at the rate of 1.0 and 3.0 mg Fe kg^{-1} soil as Fe-DTPA and Fe-EDDHA. The results showed that the application of Fe-DTPA and Fe-EDDHA significantly increased yield of groundnut as compared to the Control. The effectiveness of Fe-EDDHA in increasing yield of groundnut was higher than that of Fe-DTPA.

Ebrahimian *et al.* (2010) noticed that the effect of iron sulfate foliar application on yield of sunflower. The results showed that there was significant; drought stress led to decrease of vegetative growth, seed and oil yield, while iron foliar application significantly improved dry matter production and finally increased seed and oil yield.

Patel *et al.* (2011) reported that the effect of zinc and iron on yield and yield attributes of rainfed cowpea (*Vigna aunguculata* L.) revealed that the application of $ZnSO_4$ @ 25 kg ha^{-1} through soil proved to be most effective and increased the seed yield by 43.0 per cent compare with control followed by the spraying of 0.5 per cent $ZnSO_4$ at 25 and 45 DAS. The increase in yield was due to increase in number of pods per plant, 100-seed weight.

Heidarion *et al.* (2011) observed that the significant effect of Zn + Fe treatment on grain yield, number of pods per plant. The highest yield was recorded due to application of Zn + Fe combination treatment to soybean crop.

Kobraee *et al.* (2011) noticed that the effect of micronutrients on yield components of soybean. The three levels of Fe (0, 25, 50 kg ha^{-1}**)** source of $FeSO_4$. The highest grain yield was obtained by applying 40 kg ha^{-1} $ZnSO_4$, 50 kg ha^{-1} $FeSO_4$ and 40 kg ha^{-1} $MnSO_4$.

Babaeian *et al.* (2011) evaluated that the effect of water stress and micronutrients (Fe, Zn and Mn) on leaf chlorophyll content and sunflower nutrient uptake. The results showed that exertion of water stress in flowering and grain filling stage decreased grain yield of sunflower significantly. Use of foliar micronutrient increased grain yield in water stress. the highest chlorophyll a fluorescence was recorded in B_1 (foliar application of Fe), and maximum amount of chlorophyll content was observed in B_5 (foliar application of Fe + Mn). The highest seed contents of Fe and Mn were measured in the control treatment.

Elnaz and Ahmad (2011) studied that the iron foliar application significantly improved dry matter production and finally increased seed and oil yield. So, iron sulphate foliar application (4 parts per 1000) is recommended in sunflower farms under normal and drought stress conditions.

Galavi *et al.* (2012) observed that the effects of micronutrient foliar application on seed yield content of safflower. The micronutrient fertilizers were used at two times as: 60 days after planting and 80 days after planting. The results revealed that micronutrients foliar application had a significant effect on seed and biological yield, 1000-seed weight; but the harvest index and number of seeds per head was not significantly influenced by applied treatments. The maximum seed yield and biological yield as well as 1000 grain weight obtained from Fe treatment over control.

Mostafavi (2012) investigated that the micronutrient foliar application on soybean yield and its components. The effect of micronutrients foliar application on grain yield and number of pods per plant and 1000 grain weight was significant. Zn + Fe combination treatment had the maximum number of pods per plant (36.36). Furthermore, number of seeds per pod had positive significant correlation with 1000 grain yield. The interaction of fertilizer and time of fertilizer application showed that Fe treatment at the beginning of flowering produced maximum number of seeds per pod (2.36). Maximum 1000 grain weight was found at 10-leaf stage (168.3 g). Zn + Fe combination treatment produced maximum 1000 grain weight.

Habib (2012) reported that the foliar application of Zn and Fe increased seed yield and its quality of wheat compared with the control. Foliar feeding with urea increased seed yield and yield component.

Mohammad *et al.* (2012) studied that the effects of micronutrient foliar application of safflower. The micro nutrient fertilizers were used in two times as: 60 days after planting and 80 days after planting. The results revealed that micronutrients foliar application had a significant effect on seed biological yield, 1000 grain weight; but the harvest index and number of seeds per head was not significantly influenced by applied treatments Overall, it was concluded that micronutrient had positive effects on quantitative and qualitative traits of safflower in conditions of studied area.

Rezaei *et al.* (2013) investigated the effects of Fe foliar application on the yield and yield components of soybean (*Glycine max* L.). results of analysis of variance indicated that the interaction effects of Iron foliar application and defoliation of soybean on the characteristics of number of pods per plant, 1000 grain weight, seed yield, biological yield, were significant at the 5 per cent level, The result of the highest pod per plant,1000 grain weight, seed yield and biological yield declared were obtained under control Fe Spraying 4/1000 with average 127.1 (cm) and 944.77 (No) 47.49 SPAD 183.06 (g), 7313.3 (Kg ha^{-1}) and 29397 (Kg ha^{-1}) respectively.

Sale *et al.* (2013) evaluated that the response of zinc, iron and molybdenum on yield of soybean (*Glycine max* L.). The experimental treatments included seed fortification of Mo @ 0.66 g kg^{-1} seed at the time of seed treatment and Zn (0.5%) and Fe (0.5%) foliar spray used in three times 30, 50 and 70 days after sowing. The result revealed that micronutrients application had a significant effect on grain and straw yield content of soybean. The maximum grain and straw yield received in treatment receiving foliar application of Fe and Zn.

Ali *et al.* (2014) studied that the effect of foliar application of ($FeSO_4$) on yield of mungbean.The foliar application of 0.5%, 1% and 1.5% solutions of $FeSO_4$ both at flowering stagesgave higher number of pods per plant (44.64%), number of seeds per pod (45.31%), 1000 grain weight (18.97%), and grain yield (38.66%) of mungbean.

Baraich *et al*. (2016) revealed that the foliar application of Zn, B and Fe at rate of 8 kg ha^{-1}, 0.30 kg ha^{-1}, 0.75 kg ha^{-1} increased seed weight $head^{-1}$ and seed yield of sunflower by 21%, 27%, 13%, 34%, 19%, 24 and 31%, respectively over control.

Pallavi and Sudha (2017) reported that the recommended dose of fertilizer $ZnSO_4$ and $FeSO_4$ were applied to soil at the rate of 20 kg ha^{-1}. Two foliar applications of $ZnSO_4$ and $FeSO_4$ each @ 0.5 per cent were made at heading stage and at milking stage to wheat. Wheat crop responded significantly to the soil and foliar application of Zn and Fe. The higher number of 1000 grain weight (43 g), grain yield (38 q ha^{-1}) and biomass yield (100.7 q ha^{-1}) were recorded with soil (20 kg ha^{-1}) and foliar application (0.5%) of Fe & Zn at heading and milking stage.

Sale *et al.* (2017) noticed thatthe field experiment was conducted to study the effect of micronutrients on yield of soybean the highest grain and straw yield were observed in which recei -ves foliar spray of $ZnSO_4$ (0.5%) and $FeSO_4$ (0.5%). The lowest grain and straw yield were recorded in control.

2.4 Effect of soil and foliar application of iron on quality parameters of soybean

Salih (2013) investigated that effect of the foliar application of Fe, B and Zn on nutrient concentration and seed protein of cowpea (*Vigna Unguiculata*). In addition, three concentrations (0, 1 and 2 ppm) of micronutrient solutions were applied Fe, B and Zn were sprayed every 15 days. The effect of different treatments at 1 per cent level on nutrient concentration and seed protein were significant. Iron treatment has greater effect on the protein percentage and nutrient uptake of seed than other treatments.

Sale and Nazirkar (2013) evaluated that the response of zinc, iron and molybdenum on quality of soybean (*Glycine max* L.). The experimental treatments included seed fortification of Mo @ 0.66 g kg^{-1} seed at the time of seed treatment and Zn (0.5%) and Fe (0.5%) foliar spray used in three times 30, 50 and 70 days after sowing. They reported that the maximum oil and protein percentage was obtained with the foliar application of Fe and Zn along with seed fortification of Mo. Micronutrient had positive effect on nutrient uptake with qualitative and quantitative traits of soybean.

Ali *et al.* (2014) conducted the field experiment with consisted of foliar applications of 0.5%, 1% and 1.5% solutions of $FeSO_4$, both at branching and flowering stages. Moreover, application of $FeSO_4$ also improved the quality of mung bean by increasing protein and iron contents in grains. Application of 1.5 per cent foliar $FeSO_4$ improved the quality of grains by increasing protein contents (6.60%) and iron contents (46.39%) in grains as compared to control.

Pallavi and Sudha (2017) reported that the quality parameter like protein 14.2 per cent was significantly higher due to soil and foliar application of zinc and iron at heading and milking stage of wheat as compared to other treatments.

3. MATERIALS AND METHOD

A field experiment was conducted to evaluate the effect of soil and foliar application of iron on nutrient availability, uptake, yield and quality of soybean during *kharif* 2018. The information on the material used and experimental techniques adopted during the study period are presented in this chapter.

3.1 Experimental material

3.1.1 Experimental site

The field experiment was conducted at Agricultural Research Station, Kasbe Digraj, Dist: Sangli during *kharif* season of the year 2018. This study area is located in Deccan plateau, hot semi arid eco región, in the western Maharashtra plane zone (Zone VI) and is situated at $16^0$08' North latitude, $74^0$08' East longitude and at an altitude of 580 m above mean sea level (MSL). The site was selected on the basis of suitability of soil for growing soybean.

3.1.2 Soil of the experimental field

The experiment was conducted on medium deep soil. The topography of experimental field was fairly uniform and levelled. The soil of the experimental site was medium deep black soil. In order to know the physical and chemical compositions of experimental field, soil samples were collected from different location from experimental area and composite sample was prepared and analyzed. The relevant data regarding the physical and chemical properties of experimental soil are presented in Table 3.1. The experimental soil status was low available nitrogen (170 kg ha^{-1}), low in available phosphorus (7.5 kg ha^{-1}), very high in available potassium (433 kg ha^{-1}) and deficient in iron. The soil was slightly alkaline in reaction (pH 8.15).

3.1.3 Climatic conditions and location

3.1.3.1. General

The Agricultural Research Station, Kasbe Digraj, Dist. Sangli is situated on $16^0$08’ North latitude and $74^0$08’ East longitude. The altitude above mean sea level is about 580 metres. The average annual rainfall, is 630 mm with 65 rainy days, which are received mostly from South-West monsoon. Out of the total annual precipitation,70 per cent was received in the month of June to September from South-West monsoon. The annual maximum and minimum temperature ranges from 34^0C to 40^0C and 6^0C to 10^0C, respectively. The mean humidity percentage during season ranges between 78 to 95 per cent.

Table No.3.1 Initial physical and chemical properties of soil

Sr. No.	Particulars		Values
A	**Physical properties**		
1	Sand (%)		18.40
2	Silt (%)		32.00
3	Clay (%)		49.60
4	Soil Texture		clay
B	**Chemical properties**		
1	Soil pH		8.15
2	EC (dS m^{-1})		0.18
3	Organic carbon (%)		0.45
4	Calcium carbonate (%)		6.8
5	Available nitrogen (kg ha^{-1})		170
6	Available phosphorus (kg ha^{-1})		7.5
7	Available potassium (kg ha^{-1})		433
8	DTPA Extractable Micronutrients (mg kg^{-1})	Fe	4.05 (4.5)*
		Mn	2.52 (2.0)*
		Zn	0.35 (0.60)*
		Cu	0.40 (0.2)*

* figures in parameters indicate critical limit of micronutrients

3.1.3.2. Climatic condition

In order to get clear idea about the prevailing climatic conditions during the period of experimentation, the weekly weather data was obtained from the Department of Meteorology, Agricultural Research Station Kasbe Digraj, Dist: Sangli and presented in TableNo.3.1. The data presented in Table No. 3.2 revealed that the weekly mean maximum and minimum temperature during crop growth period ranged between 25^0C to 34^0C and 16^0C to 23^0C, respectively. The weekly mean relative humidity during the morning and evening ranged between 86% to 92% and 53% to 81% respectively. The weekly mean rainfall received during the experimental period ranged between 0.3 mm to 25 mm. The weekly mean evapotranspiration (mm hr^{-1}) ranged between 0.8 mm hr^{-1} to 9.7 mm hr^{-1}. Total rainfall received 338 mm during the crop growth period of soybean.

Table No. 3.2 Weekly weather data during the experimental period (June-2018 to October-2018)

Month and year	Metero-logical week	Mean temp. (^0C)		Relative humidity (%)		Rainfall (mm)
		Max.	Min.	Morning	Evening	
June, 2018						
28-May-03-Jun	22	35.7	23.1	86.7	69.1	35.6
04-Jun-10-Jun	23	31.9	21.8	90.1	72	10.2
11-Jun-17-Jun	24	31	21.3	87.3	70.9	0
18-Jun-24-Jun	25	31.9	21.2	93.9	74.7	51.5
25-Jun-01-Jul	26	28.4	21.9	92.1	74.4	3.2
02-Jul-08-Jul	27	26.5	22	91.3	77.3	21.2
09-Jul-15-Jul	28	24.4	21.4	82.6	67.4	27.9
16-Jul-22-Jul	29	25.5	23	89.1	71	44.1
23-Jul-29-Jul	30	26.6	23.2	90.3	72.7	4.1
30-Jul-05-Aug	31	27.1	22.3	92.9	75.4	12.4
06-Aug-12-Aug	32	27.4	21.8	92	75.9	14.8
13-Aug-19-Aug	33	27.1	20.7	92.3	79	25
20-Aug-26-Aug	34	26.8	21.4	88.8	71.1	10.6
27-Aug-02-Sep	35	27.4	22.4	86.3	69.1	11.1
03-Sep-09-Sep	36	29.1	20.9	79.9	59.7	2.4
10-Sep-16-Sep	37	29.4	19.6	80.6	57.9	0
17-Sep-23-Sep	38	30.7	20.6	83.4	64.9	3
24-Sep-30-Sep	39	31.4	20.4	87.3	65.4	59.9
01-Oct-07-Oct	40	32.4	21.9	75.9	57.6	1.2
08-Oct-14-Oct	41	33.4	23.3	79.4	58.8	0
15-Oct-21-Oct	42	33.5	21.4	87.3	64.1	0

3.2 Experimental details

3.2.1 Experimental layout

The experiment was laid out in randomized block design with eight treatments and three replications in *kharif*, 2018. The plan of layout of experiment is depicted in Fig. 3.1.

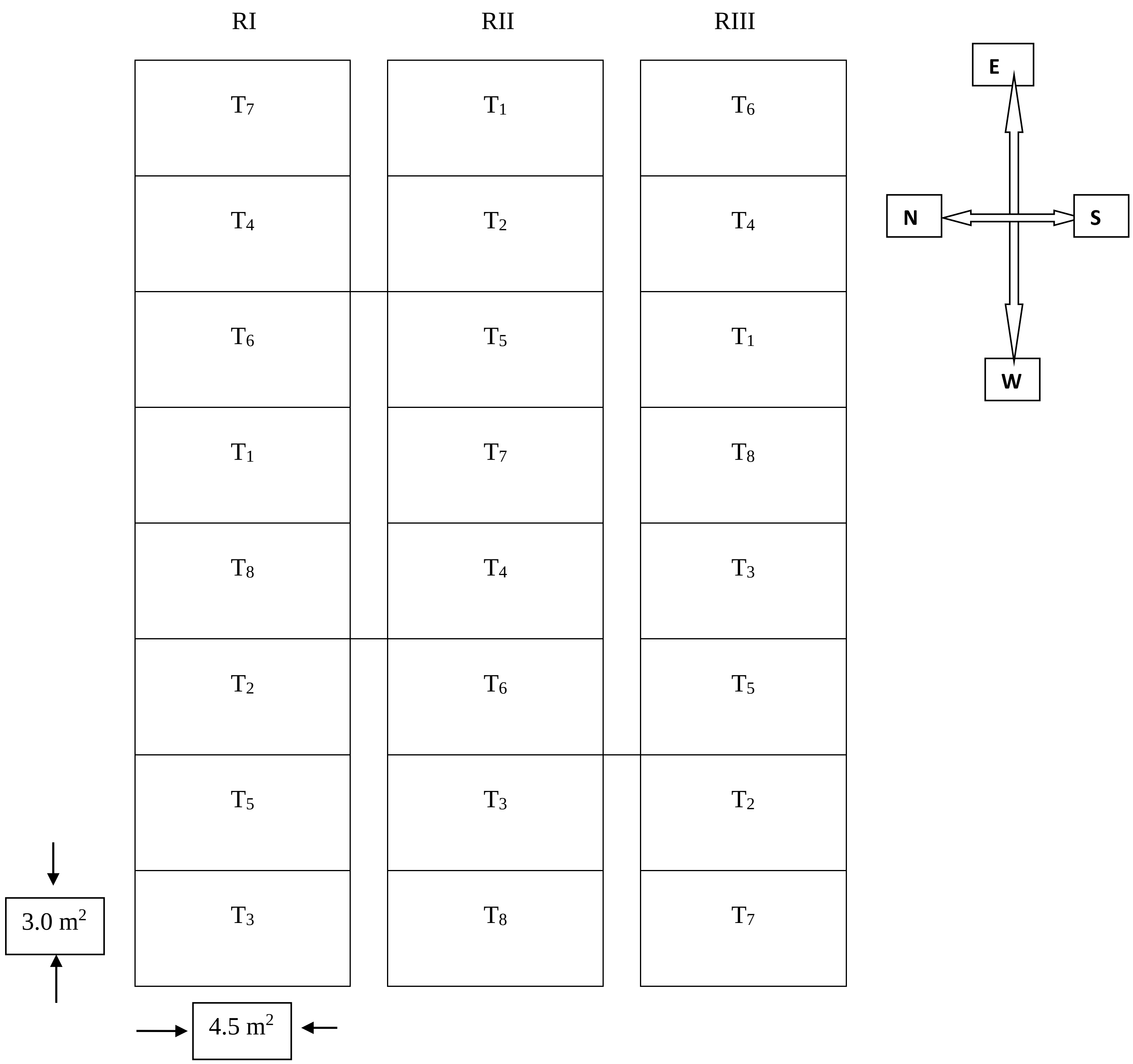

Fig. 3.1 Plan of experimental layout of plot

3.2.2 Experiment Details

1.	**No. of treatments**	:	8
2.	**Replications**	:	3
3.	**Design**	:	RBD (Randomized Block Design)
4.	**Plot size**	:	Gross-3.0 × 4.50 m^2 Net-2.70 x 4.40 m^2
5.	**Season**	:	*Kharif*
6.	**Crop**	:	Soybean
7.	**Variety**	:	*Phule Sangam* (KDS-726)
8.	**Method of sowing**	:	Dibbling
9.	**Spacing**	:	30 × 10 cm^2
10.	**Recommended dose of fertilizer**	:	50:75:45 N:P_2O_5:K_2O kg ha^{-1} +10 t FYM ha^{-1}
11.	**Date of Sowing**	:	29 June, 2018
12.	**Seed Rate**	:	80 kg ha^{-1}
13.	**Location**	:	Agricultural Research Station Kasbe Digraj, Dist: Sangli

3.2.3 Treatment detail

T_1 : Absolute control

T_2 : GRDF (50:75:45 kg ha^{-1} N:P_2O_5:K_2O + 10 t ha^{-1} FYM)

T_3 : GRDF + soil application of $FeSO_4$ @ 10 kg ha^{-1}

T_4 : GRDF + soil application of $FeSO_4$ @ 20 kg ha^{-1}

T_5 : GRDF + $FeSO_4$ @ 10 kg ha^{-1} + cow dung slurry @ 500 litre ha^{-1}

T_6 : GRDF + two foliar sprays of chelated Fe @ 0.2% at 30 and 50 days after sowing (DAS)

T_7 : GRDF + soil application of $FeSO_4$ @ 10 kg ha^{-1} + two foliar sprays of chelated Fe @ 0.2% at 30 and 50 DAS

T_8 : GRDF + soil application of $FeSO_4$ @ 20 kg ha^{-1} + two foliar sprays of chelated Fe @ 0.2% at 30 and 50 DAS

Note: Cow dung slurry (125 kg cow dung + 500 litre water) with micronutrient incubated for one week and applied in first irrigation.

Table No. 3.3A schedule of field operation carried out in experimental plot during *kharif* 2018

Sr. No.	Particulars	Frequencies	Date
A	**Preparatory tillage**		
1	Ploughing	1	22.05.2018
2	Harrowing	1	24.05.2018
3	Application of FYM	1	01.06.2018
4	Pre-sowing irrigation	1	20.06.2018
5	Preparation of field layout	1	25.06.2018
6	Seed treatment	1	29.06.2018
7	Application of fertilizer (treatment wise)	1	29.06.2018
8	sowing	1	29.06.2018
9	gap filling	1	06-07-2018
10	Application of cow dung slurry	1	11.07.2018
11	Hand weeding	2	14.07.2018
			02.08.2018
12	Chelated Fe foliar application	2	29.07.2018
			19.08.2018
13	Application of insecticides	1	30.07.2018
14	Irrigations	3	29.06.2018
			11.07.2018
			06.08.2018
15	Harvesting	1	16.10.2018
16	Threshing	1	16.10.2018

3.3.1 Preparatory tillage

The experimental site was ploughed with help of tractor and tractor drawn cultivator. The clod crushing was done by tractor drawn rotavator. The field was levelled with the help of wooden plank and was made ready for layout.

3.3.2 Fertilizer application

The soybean crop was fertilized with 50 kg N and 75 kg P_2O_5 $ha^{-1}$and 45 K_2O for treatment GRDF (General Recommended Dose of Fertilizer) full dose of N, P_2O_5 and K_2O was applied through urea, single super phosphate and muriate of potash to treatment T_2 to T_8 at the time of sowing. The treatement wise quantity of ferrous sulfate was incubated in well decomposed FYM for four days and then applied to treatment T_3, T_4, T_7 and T_8 at the time of sowing.

3.3.3 Seed treatment

The seeds of soybean variety *Phule Sangam* (KDS 726) were inoculated with *Rhizobium* and phosphate solubilising bacteria @ 250 g per 10 kg of seeds and used for sowing.

3.3.4 Sowing

Sowing was done by opening very small furrow at distance of 30 cm with the help of marker and soybean seed was dibbled at a distance of 10 cm to a depth of 3 to 4 cm and covered with soil.

3.3.5 Gap filling

The gaps were observed in experimental plots and these gaps were filled at 6 days after sowing.

3.3.6 Irrigation

Three irrigations were given during the crop growth period as per requirement with considering rainfall and crop growth stages.

3.3.7 Application of cow dung slurry

The cow dung slurry (125 kg cow dung + 500 litre water) with $FeSO_4$ @ 10 kg ha^{-1} were incubated for one week and applied to the treatment T_5 during first irrigation.

3.3.8 Foliar application

The foliar sprays of chelated Fe at the rate of 0.2 per cent at 30 and 50 DAS as were applied applied to treatment T_3, T_4, T_6, T_7 and T_8.

3.3.9 Intercultural operation

Two hand weedings and one hoeing with the help of cycle hoe were done as per the weed intensity and keep the plot was weed free.

3.3.10 Plant protection measures

Crop was sprayed two times to protect it from pest and diseases. In order to control pest and diseases, the crop was sprayed with Chlorpyriphos (0.5%) at every fortnight.

3.3.11 Harvesting

The soybean crop was harvested at physiological maturity when the pods turned yellow colour with matured seeds. The border line plants were removed first to eliminate border effect. The crop from net plot was cut close to the ground and kept in respective plots for sun drying.

3.3.12 Threshing

The plot wise threshing of soybean was done. The grains were separated from plant by mechanical thresher. The straw yield and soybean grain yield was recorded by weighing as per the treatments.

3.4 Observations

3.4.1 Plant Observations

The observations of Days of 50% flowering, plant height, number of branches plant^{-1}, number of pods plant^{-1} and 100 grain weight, root nodule per plant and grain and straw yield were recorded.

Sampling techniques: Five plants of soybean were selected randomly from each net plot by using random numbers. The selected plants were marked by fixing pegs. All the observations were recorded on these plants.

3.4.2.Growth parameters

3.4.2.1. Days to 50% flowering

The days were counted required for soybean to attain 50 % flowering.

3.4.2.2. Plant height

The height of plant were recorded at harvest. The plant height of five plants were measured from the ground level up to the growing point of plant and the average height of plant was expressed in centimetres.

3.4.2.3. Total number of branches per plant

The number of branches plant^{-1} were recorded at pod filling stage. The five randomly selected and marked plants and average of five plants were recorded at each observation for comparing treatment effects.

3.4.2.4. Number of pods

Randomly selected five plants used for counting the number of pods plant^{-1} at harvest. Then pods from each plant were removed, separated, counted and recorded under the respective treatments and then the mean was computed.

3.4.2.5.Number of root nodule

The two plants were randomly selected used for counting the number of effective nodules and non effective plant^{-1} and counted the nodule on root.

3.4.2.6. Chlorophyll content

The chlorophyll content was obtained by 30 DAS and 50 DAS of green plant samples. Chlorophyll of fresh plant leaves (4th leaf) at flowering stage extracted in 85 per cent acetone and the absorbance values at 660 nm and 642.5 nm wavelength were recorded on spectro photometer Arnon (1949)

3.4.3 Yield and yield contributing characters

3.4.3.1. Grain yield

After harvest, the grains of soybean obtained after threshing and winnowing of the produce from each net plot was sun dried and their final air-dried weight per plot was recorded in kg and was expressed in q ha^{-1}.

3.4.3.2. Straw yield

The straw yield per net plot was obtained by weighing the sun dried straw and chaff which remained after removal of grains. It was considered as straw yield per net plot (kg) and was expressed in q $ha^{-1.}$

3.4.3.3. 100 grain weight

One hundred seeds were randomly collected from the net plot yield, counted, weighed and expressed as test weight in grams.

3.4.4.Quality parameters

3.4.4.1. Protein content

The protein content in the seeds was analyzed by indirect method. First, the per cent nitrogen content of the sample was estimated by microkjeldahl method (Parkinson and Allen, 1975). Then the nitrogen value was multiplied by a factor 5.71 to get the protein content of the sample and expressed in percentage. (F.A.O. 2003).

3.4.4.2. Oil content

Oil percentage of grain was determined by Soxhlet extractor using petroleum ether as a solvent.

3.5 Methods

The analytical work was done in the research laboratory of Agricultural Research Station Kasbe Digraj, Dist: Sangli during the year 2018. The following analytical methods were employed.

3.5.1 Soil analysis

Before sowing and after harvest of crop, plot wise representative soil samples were collected and analyzed by adopting standard procedures.

1) Soil reaction (pH)

The soil pH was measured with the help of pH meter having glass electrode and calomel electrode using 1:2.5, soil: water ratio as described by Jackson (1973).

2) Electrical conductivity

It was determined with the help of conductivity meter using soil: water ratio of 1: 2.5 (Jackson 1973).

3) Organic carbon

Organic carbon in soil (0.5 mm sieved) was determined by wet oxidation method as described by Nelson and Sommers (1982).

4) Per cent calcium carbonate equivalent

Calcium carbonate in soil was determined by rapid titration method as described by Piper (1966).

5) Available nitrogen

It was determined by alkaline permanganate method (0.32% $KMnO_4$) as described by Subbiah and Asija (1956).

5) Available phosphorus

Available phosphorus was determined by Olsen's method using 0.5*M* sodium bicarbonate extractant at pH 8.5. The soil:extractant ratio was 1: 20 and the shaking time was 30 minutes. Phosphorus in the extract was determined colorimetricallyby using spectrophotometer at 740 nm wavelength (Olsen *et al.*1954).

6) Available potassium

It was extracted with neutral normal ammonium acetate (NH_4OAc, pH 7.0) and the soil:extractant ratio was 1:5 and shaking time was 5 minutes. Potassium in soil was determined by using flame photometer as described Knudsen *et al.* (1982).

7) **DTPA Extractable Micronurients (Fe, Mn, Zn and Cu)**

Ten g of air dried soil sample was shaken with 20 ml of extractant solution (0.005M DTPA + 0.01M $CaCl_2.2H_2O$ + 0.1M Tri ethanol amine, pH 7.3) for two hours. The soil suspension was filtered and the contents of micronutrientswere measured by atomic absorption spectrophotometer (Lindsay and Norvell, 1978).

Table No. 3.4 Methods used for soil and plant analysis

Sr. No.	Parameters	Methods	References
A	**Soil analysis**		
1	pH (1:2.5; Soil : Water)	Potentiometry	Jackson (1973)
2	EC (1:2.5; Soil : Water)	Conductometry	Jackson (1973)
3	Organic carbon	Walkley and Black Wet Oxidation	Nelson and Sommers (1982)
4	Calcium Carbonate equivalent	Rapid titration	Piper (1966)
5	Available nitrogen	Alkaline permanganate	Subbiah and Asija (1956)
6	Available phosphorus	Olsen (0.5*M* $NaHCO_3$ extract at pH- 8.5) method	Olsen *et al.* (1954)
7	Available potassium	Flame photometry, Neutral normal ammonium acetate (pH-7.0)	Knudsen *et al.* (1982)
8	DTPA extractable Micronutrients (Fe,Mn,Zn and Cu)	Atomic Absorption spectrophotometry	Lindsay and Norvell (1978)
B	**Plant analysis**		
1.	Total N	Microkjeldahl method (Digestion distillation)	Parkinson and Allen (1975)
2.	Total P	Vanadomolybdate yellow colour method	Piper (1966)
3.	Total K	Flame photometry	Chapman and pratt (1961)
4.	Micronutrients (Fe,Mn,Cu and Zn)	Atomic Absorption spectrophotometry	Zososki and Burau (1977)
5.	Chlorophyll content	Colorimetry	Arnon (1949)
C	**Quality parameters**		
1	Protein	Microkjeldahl nitrogen x 5.71	F.A.O. (2003)
2	Oil content	Soxhlet ether extract	A.O.A.C. (2016)

3.5.2 Plant samples

Plant samples were collected at the time of harvest of soybean, then washed with 0.1 N HCL and then double glass distilled water, tapped with clean filter paper and then air dried and oven dried at 60^0C for 6 hours. The grain samples were collected separately and air dried. The plant and grain samples were ground separately and used for the estimation of nitrogen, phosphorus, potassium and micronutrients.

1. Total nitrogen

The plant samples (0.5 g each) were digested by using concentrated H_2SO_4 (10 ml) and H_2O_2 (10 ml). The volume was made 100 ml with distilled water to after digestion of sample. A suitable aliquot was taken for distillation and nitrogen was determined by MicroKjeldahl method (Parkinson and Allen, 1975).

2. Total phosphorus

The plant samples (0.5 g each) were wet digested with nitric acid and perchloric acid, hydrogen peroxide. The volume was made 50 ml with distilled water after digestion and was used for determination of phosphorus, yellow colour was developed with combined HNO_3 Vandomolybdate reagent by using spectrophotometer at 470 nm wavelength (Piper, 1966)

3. Total potassium

The plant samples (0.5 g each) were digested by using concentrated nitric acid and perchloric acid, hydrogen peroxide. The volume was made to 100 mL with distilled water after digestion and was used for determination potassium (Chapman and Pratt, 1961).

4. Micronurients (Fe, Mn, Zn, and Cu)

The plant sample (0.5 g each) were wet digested with nitric acid and perchloric acid in ratio 9:4 and the volume was make up to 100 ml with double distilled water after digestion. Micronutrients from plant sample were determined by Atomic Absorption Specrtrophotometer as described by Zososki and Burau (1977).

3.5.3 Uptake of nutrients by soybean

The uptake of nitrogen, phosphorus and potassium (kg ha^{-1}) was worked out by multiplying the percentage of these nutrients in grain and straw with the corresponding yields of the respective constituent. The nutrient uptake by soybean at harvest was worked out using the following equation.

$$\text{Macronutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{Dry matter yield (kg ha}^{-1}\text{)}}{100}$$

$$\text{Micronutrient uptake (g ha}^{-1}\text{)} = \frac{\text{Nutrient content (mg kg}^{1}\text{)} \times \text{Dry matter yield (kg ha}^{-1}\text{)}}{1000}$$

3.5.4 Iron use efficiency

Iron use efficiency parameters were calculated for each treatment following equations (Fageria, 2004).

$$\text{Iron use efficiency (kg kg}^{-1}\text{)} = \frac{\text{Grain yield of the iron fertilized treatment (kg) - Grain yield of the iron unfertilized treatment (kg)}}{\text{Quantity of Feapplied (kg)}}$$

3.5.5 Economics

Input prices in rupees that were prevailing at the time of their use were considered for working out the cost of cultivation. The price of the economic yield soon after harvest of the crop was used for calculating gross income. Net returns Rs. ha^{-1} was calculated by deducting the total cost of cultivation Rs. ha^{-1} from gross return. Benefit: cost ratio was worked out as fallows.

$$\text{B: C ratio} = \frac{\text{Gross return (Rs. ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs. ha}^{-1}\text{)}}$$

3.6 Statistical Analysis

The experimental data were analysed statistically by applying the technique of “Analysis of variance” and significance was tested by variance ratio i.e. F value at 5 per cent level of significance as described by Panse and Sukhatme, (1985) Standard error of mean (S.Em.) and critical difference (CD) was worked out to evaluate differences between treatment means.

4. RESULTS AND DISCUSSION

The present investigation was carried out to study the "Effect of soil and foliar application of iron on nutrient availability, uptake, yield and quality of soybean" was conducted during *Kharif* 2018. The results of the said investigation are presented below under appropriate subheadings.

4.1 Effect of soil and foliar application of iron on growth parameters of soybean

4.2 Effect of soil and foliar application of iron on yield and yield contributing characters of soybean

4.3 Effect of soil and foliar application of iron on quality parameters of soybean

4.4 Effect of soil and foliar application of iron on nutrient content and uptake of soybean

4.5 Effect of soil and foliar application of iron on soil chemical properties after harvest of soybean

4.6 Effect of soil and foliar application of iron on iron use efficiency

4.7 Effect of soil and foliar application of iron on economics of soybean

4.1 Effect of soil and foliar application of iron on growth parameters of soybean

Significant differences were noticed with respect to chlorophyll content at 30 and 50 DAS, days to 50 per cent flowering, height of plant, number of branches plant^{-1}, number of pods plant^{-1} and number of root nodules per plant.

4.1.1 Chlorophyll content at 30 and 50 DAS

The data on chlorophyll content in leaves of soybean as influenced by different treatments of soil application and foliar spray of iron is presented in Table 4.1 and graphically depicted in Fig 4.1.

The chlorophyll content was indicative of the essential role of nutrients in its synthesis. Chlorophyll content in leaves also differed significantly due to soil application of iron and foliar sprays treatments. The soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2% (T_8) had recorded significantly the higher chlorophyll content at 30 and 50 DAS (20.28 mg g^{-1}) and (21.95 mg g^{-1}) over the rest of treatments. The soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2% was on par with soil application $FeSO_4$ @ 10 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2% at 30 and 50 DAS of chlorophyll (19.49 mg g^{-1}) and (21.15 mg g^{-1}) and soil application of $FeSO_4$ @ 20 kg ha^{-1}. The soil application of $FeSO_4$ @ 10 or 20 kg ha^{-1} and foliar application of chelated Fe 0.2% at 30 and 50 DAS treatments were found higher chlorophyll content at 30 and 50 DAS as compare to GRDF (T_2) and absolute control (T_1). The treatment (T_1) i.e. absolute control showed that the lowest chlorophyll content at 30 and 50 DAS as compare to other remaining treatments. However, application of FYM treatments showed numerically higher value of chlorophyll content at 30 and 50 DAS as compare to control. Application of farmyard manure (FYM) also enhances the growth parameters by solubilization effect of plant nutrients. The chlorophyll content in leaves at 50 DAS recorded higher over the chlorophyll content at 30 DAS.

The soil application of $FeSO_4$ @ 10 or 20 kg ha^{-1} and two sprays of chelated Fe @ 0.2% found higher chlorophyll content in leaves might due to the beneficial effect of $FeSO_4$ application to soil along with foliar spray increased iron availability in soil and ferrous iron (Fe^{2+}) uptake by plant leaves in foliar resulting in better absorption and translocation of iron. Which in turn might have helped the cellular activity and also directly or indirectly participate in the formation of chlorophyll and thus increasing photosynthesis.

4.1.2 Days to 50% flowering

The data regarding to average number of days taken to 50 per cent flowering as influenced by application of iron through soil and foliar are presented in Table 4.1

The average number of days to 50 per cent flowering was indicative of the higher growth rate. Days to 50 per cent flowering also differed significantly due to different treatment application of iron through soil and foliar. The significantly higher average number of days to 50 per cent flowering (44.33) was noticed in soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2% at 30 and 50 DAS (44.33) over the rest of other treatments. The soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2% (T_8) was at par with soil application $FeSO_4$ @ 10 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2% (T_7) at 30 and 50 DAS (43.66). The treatments T_2 to T_7 were at par with each other for average number of days to 50 per cent flowering. All the treatments with Fe and FYM were significantly superior over the control (38.68). The application of Fe fertilizer with FYM took longer period for average number of days to 50 per cent flowering. This might be due to the $FeSO_4$ along with FYM treatments enhances the growth by mineralisation and availability of essential nutrients to soybean and increases the uptake of nutrients and more vegetative growth of soybean. The treatment (T_1) i.e. absolute control showed that the lowest average number of days to 50 per cent flowering as compare to other remaining treatments. This may be due to less availability of essential nutrients to soybean and decreased the uptake of nutrients and less vegetative growth of soybean.

Table 4.1 Effect of soil and foliar application of iron on chlorophyll content and number of days to 50 per cent flowering of soybean

Tr. No.	Treatments	Chlorophyll content fresh weight (mg g^{-1})		Days to 50 per cent flowering
		30 DAS	50 DAS	
T_1	Absolute control	16.11	16.45	38.68
T_2	GRDF (50:75:45 kg ha^{-1} N: P_2O_5:K_2O + 10 t ha^{-1} FYM)	17.25	17.26	42.00
T_3	GRDF+ $FeSO_4$ @ 10 kg ha^{-1}	17.62	18.02	42.68
T_4	GRDF+ $FeSO_4$ @ 20 kg ha^{-1}	18.21	18.88	43.00
T_5	GRDF+ $FeSO_4$ @ 10 kg ha^{-1} + cow dung slurry @ 500-liter ha^{-1}	17.76	18.26	42.00
T_6	GRDF+ two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	16.92	20.05	41.66
T_7	GRDF+ $FeSO_4$ @ 10 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	19.49	21.15	43.66
T_8	GRDF + $FeSO_4$ @ 20 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	20.28	21.95	44.33
	SE$\pm$	0.71	0.59	0.54
	CD at 5 %	2.17	1.81	1.66

4.1.3 Plant height

The data in respect of plant height of soybean after flowering as affected by iron application through soil and foliar are recorded in Table 4.2 and graphically represented in Fig 4.2.

The plant height is indicative of the vigour and growth of plant. From the Table 4.2., it was observed that the plant height of soybean crop was significantly influenced by iron application through soil and foliar treatments. The plant height of soybean increased significantly under all the treatments over control. The treatment T_2 *i.e.* general recommended dose of fertilizer + 10 t ha^{-1} FYM was recorded significantly higher plant height as compare to control. The application of chemical fertilizers along with FYM resulted in the increase in growth attributes may be due to better uptake and translocation of plant nutrients to growing plants and more photosynthesis which in turn promoted more number of leaves, leaf area and dry matter production and found beneficial effect on plant height of soybean. The soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2% at 30 and 50 DAS (T_8) was noticed the significantly higher plant height (86.33 cm) than the rest of treatments. The treatment T_8 was on par with soil application $FeSO_4$ @ 10 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2% at 30 and 50 DAS (T_7) for plant height (85.00 cm), T_4 (83.33 cm) and T_6 (84.00 cm). It clearly indicated that GRDF along with soil application of $FeSO_4$ @ 10 and 20 kg ha^{-1} with two sprays of chelated Fe 0.2% treatments were found higher plant height. The application of Fe resulted in the increase in chlorophyll content and more photosynthesis also FYM had more beneficial and significant effect on plant height. Similar results were also reported by Balachander *et al*. (2003) reported that the application of iron at 2 kg ha^{-1} through ferrous sulphate significantly increased the plant height of black gram over control. Agrawal *et al*. (2004) also found that the application 0.5% foliar spray of $FeSO_4$ at 30, 40 and 50 days after transplanting to hybrid tomato (Cv. Avinash-2) was recorded maximum plant height of hybrid tomato.

4.1.4 Number of branches per plant

The data pertaining to number of branches per plant of soybean as differed by iron application through soil and foliar are given in Table 4.2 and graphically depicted in Fig 4.4.

The data on number of branches per plant of soybean (Table 4.2) indicated that the treatment effects were found to be statistically significant. The more number of branches (11.00 $plant^{-1}$) was recorded in soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2% over the rest of treatments.

The treatment T_8 *i.e.* soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2% was resembles with soil application $FeSO_4$ @ 10 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent at 30 and 50 DAS for number of branches (10.66

plant^{-1}) and soil application of $FeSO_4$ @ 20 kg ha^{-1} (T_4 (10.00 plant^{-1}) as well as two foliar sprays of chelated Fe @ 0.2 per cent at 30 and 50 DAS (T_6 10.00 plant^{-1}) and $FeSO_4$ @ 10 kg ha^{-1} + cow dung slurry @ 500 liter ha^{-1} (T_5 9.66 plant^{-1}).

The soil application of $FeSO_4$ @ 10 or 20 kg ha^{-1} and foliar application of chelated Fe 0.2 per cent at 30 and 50 DAS treatments were showed that the higher number of branches per plant in T_1 as compare to GRDF (T_2) and absolute control (T_1). While the lowest number of branches per plant as compare to other remaining treatments. However, application of FYM treatments showed the numerically the higher number of branches as compare to control. The soil application of $FeSO_4$ @ 10 or 20 kg ha^{-1} and two sprays of chelated Fe @ 0.2 per cent higher number of branches in soybean were increase due to the combined application of Fe, Significant increase number of branches increase in the Fe with GRDF levels, attributed to the increased uptake of nutrients in the plants leading to enhanced chlorophyll content and carbohydrate synthesis, which might have helped in number of branches per plant of soybean. Similar results were also noticed by Kumar *et al.* (2009) reported that the branches per plant increased with levels of iron up to 10 kg ha^{-1} over control in chickpea.

4.1.5 Number of pods per plant

The regarding data to number of pods per plant of soybean as influenced by iron application through soil and foliar sprays are presented in Table 4.2 and graphically depicted in Fig 4.3.

The number of pods per plant differed significantly due to iron application through soil and foliar sprays. The soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent (T_8) obtained the significantly more number of pods (44.00 plant^{-1}) over the rest of treatments. Soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent was at par with soil application $FeSO_4$ @ 10 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent at 30 and 50 DAS for number of pods (T_7 43.33 plant^{-1}) and soil application of $FeSO_4$ @ 20 kg ha^{-1} (T_4 41.33 plant^{-1}) for number of pods. The highest pods plant^{-1} was produced due to foliar application at flowering stage and increase of number of pods plant^{-1} due to foliar application could be attributed to significant effect iron on reproductive organs, such as stamens and pollens (Seifi Nadergholi *et al.* 2011).

The soil application of $FeSO_4$ @ 10 or 20 kg ha^{-1} and foliar application of chelated Fe @ 0.2 per cent at 30 and 50 DAS treatments recorded higher number of pods as compare to absolute control (T_1). Absolute control exhibited the smaller number of pods plant^{-1} over the fertilizer receiving treatments. However, application of FYM treatments showed the numerically the higher number of pods per plant compare to control.

The soil application of $FeSO_4$ @ 10 or 20 kg ha^{-1} and two sprays of chelated Fe @ 0.2 per cent at 30 and 50 DAS was produced greater number of pods. This might be due to iron is involved in the chlorophyll synthesis pathway. Application of FYM would have helped in the plant metabolic activity through the supply of such important micronutrients in the early crop growth phase, which in turn encouraged vigorous growth and ultimately increased the number of pods per plant. Bahure *et al*. (2016) also reported that the better utilization of available resource at combination of Zn, Fe and Mg soil and foliar application which resulted in more photosynthesis and hence a greater number of pods was produced. The increase in number of pods of soybean was confirmation of the translocation of photosynthates to the productive sink. Application of Fe increases the number of pods per plant in mothbean (Sachendra *et al.*2006).

Table 4.2 Effect of soil and foliar application of iron on growth parameters of soybean

Tr. No.	Treatments	Plant height at flowering stage (cm)	Number of branches plant^{-1} at flowering stage	Number of pods plant^{-1} at harvest
T_1	Absolute control	75.00	8.00	29.33
T_2	GRDF (50:75:45 kg ha^{-1} N: P_2O_5:K_2O + 10 t ha^{-1} FYM)	80.00	8.66	37.66
T_3	GRDF+ $FeSO_4$ @ 10 kg ha^{-1}	81.00	9.33	38.66
T_4	GRDF+ $FeSO_4$ @ 20 kg ha^{-1}	83.33	10.00	41.33
T_5	GRDF+ $FeSO_4$ @ 10 kg ha^{-1} + cow dung slurry @ 500-liter ha^{-1}	81.66	9.66	40.66
T_6	GRDF+ two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	84.00	10.00	40.66
T_7	GRDF+ $FeSO_4$ @ 10 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	85.00	10.66	43.33
T_8	GRDF + $FeSO_4$ @ 20 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	86.33	11.00	44.00
	SE$\pm$	0.97	0.54	0.93
	CD at 5%	2.95	1.66	2.85

4.1.6 Root nodules per plant

The data in respect of number of effective and non-effective root nodules per plant as influenced by different treatments of soil and foliar sprays are presented in Table 4.3.

Significantly more number of effective root nodules (44.33) were noticed in soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent treatment than the rest of remaining treatments. This might be due to soybean is a legume, which develop symbiotic relationships with nitrogen-fixing bacteria, have an increased demand for the micronutrient. Both the plant and bacteria individually have an innate requirement, but it is also essential for the establishment, development and function of the symbiosis. The more available iron content was observed in soil as well as direct absorption of iron through foliar sprays. Iron is required for the synthesis of Fe containing proteins in the host including leg haemoglobin and in bacteriods for nitrogenase and cytochromes of the electron transport chain. Similar results also observed by Shukla and Shukla (1994) at Allahabad, India applied 25 and 50 kg $FeSO_4$ ha^{-1} to chickpea crop which resulted in increased number of nodules per plant, dry weight of root nodules, leghaemoglobin content of root nodules and rate of N_2 fixation as compared to control treatment. The soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent was found non-significant effect with soil application $FeSO_4$ @ 10 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent at 30 and 50 DAS (T_7) and soil application of $FeSO_4$ @ 20 kg ha^{-1} (T_4). It clearly indicated that basal application $FeSO_4$ @ 10 or 20 kg ha^{-1} were increased the nodule count. The soil application of $FeSO_4$ @ 10 or 20 kg ha^{-1} and foliar application of chelated Fe 0.2 per cent at 30 and 50 DAS treatments were found higher number of effective root nodules at 30 and 50 DAS as compare to GRDF (T_2) and absolute control (T_1). The treatment (T_1) *i.e* absolute control showed that the lowest number of effective root nodules at 30 and 50 DAS as compare to other remaining treatments. However, application of FYM treatments showed the numerically the higher number of effective root nodules at 30 and 50 DAS as compare to control. The soil application of ferrous sulphate at 25 kg ha^{-1} to soybean crop increased nodulation, nodules dry weight per plant as compared to control (Bhanavase *et al*. 1994). Sale *et al.* (2017) who had also reported the number of nodules responded significantly Fe application in Fe deficient soil. The reverse trend was observed in respect of non-effective root nodules per plant of soybean.

Table 4.3 Effect of soil and foliar application of iron on number of root nodules per plant of soybean

Tr. No.	Treatments	Number of root nodules plant^{-1} at flowering	
		Effective	Non-effective
T_1	Absolute control	31.33	16.33
T_2	GRDF (50:75:45 kg ha^{-1} N: P_2O_5:K_2O + 10 t ha^{-1} FYM)	36.66	15.00
T_3	GRDF+ $FeSO_4$ @ 10 kg ha^{-1}	38.00	13.00
T_4	GRDF+ $FeSO_4$ @ 20 kg ha^{-1}	40.66	12.33
T_5	GRDF+ $FeSO_4$ @ 10 kg ha^{-1} + cow dung slurry @ 500-liter ha^{-1}	38.33	11.33
T_6	GRDF+ two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	39.33	12.33
T_7	GRDF+ $FeSO_4$ @ 10 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	42.33	7.00
T_8	GRDF + $FeSO_4$ @ 20 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	44.33	8.00
	SE$\pm$	1.50	0.82
	CD at 5 %	4.55	2.50

4.2 Effect of soil and foliar application of iron on grain yield and straw yield contributing characters of soybean

4.2.1 Grain yield

The data pertaining to grain yield of soybean as influenced by different treatments of soil and foliar sprays of iron are presented in Table 4.4 and graphically depicted in Fig. 4.5.

The data presented in Table 4.4 revealed that the grain yield of soybean was significantly influenced by different treatments of soil and foliar sprays of iron. The significantly lowest yield was noticed in absolute control as compare to rest of the treatments. The treatment GRDF (T_2) was at par with treatments T_3 to T_7 for grain yield of soybean. The significantly higher grain yield (24.93 q ha^{-1}) was obtained in soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent (T_8) over the rest of treatments. The percent increase in grain yield by soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent to the soybean was 14 per cent over the T_2 GRDF treatment and 81 per cent over the control. The highest yield recorded due to soil and foliar application of $FeSO_4$ might be due to quicker availability of iron to plants, soil applied $FeSO_4$ and FYM might have resulted in formation of metalo-organic complexes of higher extractability and helped in continuous supply of iron and this in turn increases catalase and chlorophyll content and also manufacture and accumulate more carbohydrates, which seems to be associated with increase in flowing and pod development ultimately increasing grain yield of soybean. The results confirm the findings of Sale *et al.* (2013) who had also reported this result might be due to the enhancement of enzymatic activity in microelements which effectively increase photosynthesis and ultimately translocation of assimilation to seeds. Similar results were also observed by Bybordi and Mamedor, (2010) result may be due to provision of micronutrients at latter stage which might have enhanced accumulation of assimilate in seeds.

The soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent was at par with soil application $FeSO_4$ @ 10 kg ha^{-1} along with two foliar sprays of chelated Fe 0.2 per cent (T_7 23.24 q ha^{-1}) and soil application of $FeSO_4$ @ 20 kg ha^{-1} (T_4 23.14 q ha^{-1}) for grain yield. The soil application of $FeSO_4$ @ 10 & 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent was recorded higher grain yield as compare to soil application of $FeSO_4$ @ 10 & 20 kg ha^{-1} only. The increase in yield with soil applied Fe might have been the result of increase in the content of available Fe in the soil as well as the increase in yield with foliar application of Fe could be attributed to the direct absorption of the element by the foliage sprayed with Fe solution. The significantly highest grain yield of soybean was noticed in GRDF over the control. The beneficial and significant effect of farmyard manure on growth and yield parameters might be its role in improving physical properties of soil. It is good source of nutrients and also helps in enhancing the availability of nutrients in soil. Similar results were obtained by Madegowda (1997) in maize.

4.2.2 Straw yield

The data in respect of straw yield of soybean as influenced by soil application and foliar sprays of iron and their combinations are given in Table 4.4 and graphically depicted in Fig 4.6.

The data presented in Table 4.4. show that the straw yield of soybean was differ statistically. The soil application of @ 10 & 20 kg ha^{-1} was recorded the significantly highest straw yield 34.79 & 36.33 q ha^{-1} respectively over the control. The treatment T_3 to T_7 was at par with each other for straw yield of soybean. The combine soil and foliar application of iron may be better availability of Fe and its uptake could be assigned as the proper reason for significant increase in dry matter production and its accumulation in soil application and foliar spray treatments. Application of Fe improved the dry matter yield of pea (Rehman and Shah, 2018).

The application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent was noticed significantly highest straw yield of soybean (37.79 q ha^{-1}) as compare to rest of the remaining treatments. The per cent increase in straw yield under the treatment T_8 was 54 per cent over the control and 14 per centover the GRDF. The application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent was on par with soil application $FeSO_4$ @ 10 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent at 30 and 50 DAS for straw yield (36.38 q ha^{-1}) soil application of $FeSO_4$ @ 20 kg ha^{-1} higher straw yield T_4 (36.33 q ha^{-1}) or $FeSO_4$ @ 10 kg ha^{-1} (T_3 34.79 q ha^{-1}) and two foliar sprays of chelated Fe 0.2 per cent at 30 and 50 DAS T_5 (35.28 q ha^{-1}) and $FeSO_4$ @ 20 kg ha^{-1} + cow dung slurry @ 500 liter ha^{-1} straw yield T_6 (35.20 q ha^{-1}).

The soil application of $FeSO_4$ @ 10 or 20 kg ha^{-1} and foliar application of chelated Fe 0.2 per cent at 30 and 50 DAS treatments were found superior over to only soil application of $FeSO_4$ @ 10 or 20 kg ha^{-1} for straw yield. The increase in straw yield of soybean may be attributed due to increased number of branches, increased plant height, more root nodules and more seed density, dry matter production may be combined application of soil major and micronutrients at different stages of crop growth. Similar results were noticed by Rehman and Shah *et al.* (2018) who had reported that the micronutrients play and critical role in plant that lead to increase leaf area index and thereby increase light absorption and increase the amount of dry matter (straw yield). Absolute control exhibited that the significantly lowest straw yield of soybean as compare to other remaining treatments.

4.2.3 100 grain weight

The data pertaining to 100 grain weight of soybean as differed by soil application and foliar sprays of iron are given in Table 4.4.

The data on 100 grain weight (Table 4.4.), indicated of the treatment effects were found to be significant. The soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent had recorded the significantly higher 100 grain weight (19.20 g) over the rest of treatments. The reason for increased 100 grain weight might be attributed to enhanced photosynthetic activity due to increased chlorophyll content in leaves. This has resulted in the production and accumulation of carbohydrates in 100 grain weight development.

The soil application of $FeSO_4$ @ 10 & 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent treatments were found to be non-significant. However, soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent treatments significantly superior over the GRDF (17.7) and control (17.1). It clearly indicated that the application of iron through soil and foliar was beneficial for increasing 100 grain weight of soybean. Similar results were also recorded by Mohammad *et al.* (2012) foliar spray of micronutrient had a significant effect on 1000 seed weight safflower. Ali *et al.* (2014) reported that foliar application of 0.5%, 1% and 1.5% solutions of $FeSO_4$ both at flowering stages gave 1000 grain weight (18.97) of mungbean. Absolute control treatment was recorded the lowest 100 grain weight over the rest of other treatments.

Table 4.4 Effect of soil and foliar application of iron on grain yield and straw yield contributing parameter of soybean

Tr. No.	Treatments	Grain yield	Straw yield	100 grain weight
		----(q ha^{-1})----		(g)
T_1	Absolute control	13.72	20.70	17.1
T_2	GRDF (50:75:45 kg ha^{-1} N: P_2O_5:K_2O + 10 t ha^{-1} FYM)	21.80	33.05	17.7
T_3	GRDF + $FeSO_4$ @ 10 kg ha^{-1}	22.12	34.79	18.2
T_4	GRDF + $FeSO_4$ @ 20 kg ha^{-1}	23.14	36.33	18.9
T_5	GRDF + $FeSO_4$ @ 10 kg ha^{-1} + cow dung slurry @ 500-liter ha^{-1}	22.37	35.28	18.7
T_6	GRDF + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	22.19	35.20	18.3
T_7	GRDF + $FeSO_4$ @ 10 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	23.24	36.38	19.0
T_8	GRDF + $FeSO_4$ @ 20 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	24.93	37.79	19.2
	SE$\pm$	0.70	1.52	0.40
	CD at 5%	2.12	4.62	1.23

4.3 Effect of soil and foliar application of iron on quality parameters of soybean

4.3.1 Oil content and oil yield

The data in respect of oil percentage and oil yield as influenced by different treatments of soil application and foliar sprays of iron are given in Table 4.5 and graphically depicted in Fig 4.7.

Soybean is being an oilseed crop grown for oil extraction. Although, oil content in soybean grain is a genetic factor but, also greatly influenced by environment and management practices.

The data presented in Table 4.5 revealed that the oil content in seed was not influenced significantly due to various treatments. However, the oil yield was significantly influenced by various treatments. The soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent recorded the significantly higher oil content (19.46%) and oil yield (485 kg ha^{-1}) over the rest of treatments. The higher oil yield may be due to better supply of nutrient elements to plants that can lead to increase of seed oil percentage and in turn oil yield. Due to enhancement of enzymatic activity and micronutrient supply there is increased rate of photosynthesis and translocation of assimilates to the seeds (Ravi *et al.* 2008).

The soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent was at par with soil application of $FeSO_4$ @ 10 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent at 30 and 50 DAS for oil yield (T_7 446 kg ha^{-1}) and soil application of $FeSO_4$ @ 20 kg ha^{-1} (T_4 444 kg ha^{-1}).

The soil application of $FeSO_4$ @ 10 or 20 kg ha^{-1} and foliar application of chelated Fe 0.2 per cent at 30 and 50 DAS and GRDF treatments recorded higher oil yield over the control. It clearly indicated that the application of iron through soil and foliar was beneficial for increasing oil yield of soybean. Ferrous sulphate also contains sulphur in addition to iron. Sulphur is one of the important secondary nutrients required by the crops, sulphur along with iron might have helped to obtain higher oil yield of soybean. Higher oil yield may be due to higher iron availability in alkaline soils, which ensured better biosynthesis of oil in groundnut (Poonia *et al.* 2018). The lowest oil content (18.40%) and oil yield (252 kg ha^{-1}) was noticed in treatment ($T_{1)}$ i.e. absolute control than the rest of other remaining treatments.

4.3.2 Crude protein content and protein yield

The data pertaining to crude protein content in seed and crude protein yield as influenced by different treatments of soil application and foliar sprays of iron and its combination are presented Table 4.5 and graphically depicted in Fig 4.8.

It is evident from the Table 4.5, that protein content in seed and protein yield were significantly influenced by various treatments. The application of Fe either through soil as well as foliar sprays recorded higher values of crude protein content and protein yield of soybean as compare to control.

Significantly lower crude protein (24.82%) and crude protein yield (340 kg ha^{-1}) were recorded in without FYM and fertilizers over the rest of treatments. However, the significantly higher crude protein (29.60%) and crude protein yield (738 kg ha^{-1}) noticed in treatment soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent as compare to rest of treatments. The treatments T_2 to T_7 were at par with each other for crude protein content in soybean. The soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent was at par with soil application $FeSO_4$ @ 10 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent at 30 and 50 DAS (T_7 681 kg ha^{-1}) and soil application of $FeSO_4$ @ 20 kg ha^{-1} (T_4 681 kg ha^{-1}) for crude protein yield of soybean. It clearly indicated that application of iron is beneficial for increasing crude protein content and crude protein yield of soybean, this might be due to iron is essential for nitrogen fixation and better availability of nitrogen and it absorption ultimately increases in protein content in grain of soybean. Similar results were close in conformity with Sale *et al.* (2017) they reported that the foliar application Fe had significant effect on protein yield.

The soil application of $FeSO_4$ @ 10 or 20 kg ha^{-1} and foliar application of chelated Fe @ 0.2 per cent at 30 and 50 DAS treatments recorded crude protein and crude protein yield over the GRDF (T_2) and absolute control (T_1). The increase in protein content and protein yield might be due to Fe is important element of structure of enzyme involved in amino acid synthesis ultimately protein synthesis and thereby increase in protein content with the application of iron.

Table 4.5 Effect of soil and foliar application of iron on quality parameters of soybean

Tr. No.	Treatments	Oil	Crude protein	Oil yield	Crude protein yield
		----(%)---		----(kg ha^{-1})----	
T_1	Absolute control	18.40	24.82	252	340
T_2	GRDF (50:75:45 kg ha^{-1} $N:P_2O_5:K_2O$ + 10 t ha^{-1} FYM)	18.83	28.13	410	613
T_3	GRDF + $FeSO_4$ @ 10 kg ha^{-1}	19.00	28.28	420	625
T_4	GRDF + $FeSO_4$ @ 20 kg ha^{-1}	19.20	29.43	444	681
T_5	GRDF + $FeSO_4$ @ 10 kg ha^{-1} + cow dung slurry @ 500-liter ha^{-1}	19.40	28.80	434	644
T_6	GRDF + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	19.06	29.14	422	646
T_7	GRDF + $FeSO_4$ @ 10 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	19.20	29.31	446	681
T_8	GRDF + $FeSO_4$ @ 20 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	19.46	29.60	485	738
	SE±	0.28	1.07	15.89	28.60
	CD at 5%	NS	3.25	48.20	86.73

4.4 Effect of soil and foliar application of iron on nutrient content and uptake by soybean

4.4.1 Nitrogen content and uptake of soybean

The data in respect of nitrogen content, uptake by grain, straw and total nitrogen uptake by soybean crop as influenced by different treatments of soil application and foliar sprays of iron are given in Table 4.6 and graphically depicted in Fig 4.9.

The data revealed that nitrogen content in grain and straw of soybean did not statistically influenced by different treatments. The higher N content in grain and straw (5.2%) and (0.83%) was noticed in soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent (T_8) over the rest of treatments. The N content in grain was numerically higher as compare to straw of soybean. The higher values of N content in grain and straw were observed in treatments receiving the soil application of $FeSO_4$ @ 10 or 20 kg ha^{-1} and foliar sprays of chelated Fe @ 0.2 per cent at 30 and 50 DAS alone and its combination along with GRDF over absolute control (T_1).

The N uptake in grain and straw of soybean was significantly influenced due to various treatments. The significantly higher N uptake in grain (109.16 kg ha^{-1}) and straw (24.52 kg ha^{-1}) were noticed in soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent followed by treatment T_7 (grain 100.81 kg ha^{-1} and straw 23.01 kg ha^{-1}).The treatments T_8, T_7 and T_4 were at par with other for N uptake in grain and straw of soybean. The significantly lowest nitrogen uptake in grain (50.30 kg ha^{-1}) and straw (11.36 kg ha^{-1}) of soybean was obtained in treatment without fertilizer.

It was evident that all the treatments significantly differ in increasing the total nitrogen uptake by soybean over control (61.66 kg ha^{-1}). The maximum total uptake of nitrogen 133.68 kg ha^{-1} by soybean was observed under the treatment T_8 (soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2%) which was at par with T_7 (123.81 kg ha^{-1}) and T_4 (123.29 kg ha^{-1}). The treatments T_2 to T_7 were at par with each other for total uptake of nitrogen. It clearly indicated that the better total uptake of nitrogen in soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent than other treatments for their growth and development.

The increase in uptake of nitrogen may be attributed to higher uptake of N due to high dry matter production and its further translocation to grain and straw. Further, applied Fe helped in the uptake of other nutrients including N, through activation enzymes in soil (Das, 1996). Fe which is required in N_2 fixation process of legumes as it engaged in the chemical process of different enzymes reactions, leghaemoglobin, ferredoxin, hydrogenase and cytochromes (Scherer *et al.* 2008). The treatment receiving's of $FeSO_4$ @ 10 and 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent was more total uptake of nitrogen as compare to foliar sprays of chelated Fe @ 0.2 per cent and $FeSO_4$ @ 10 kg ha^{-1}. The effect of soil and foliar application of $FeSO_4$ which extracting the micronutrient from soil by crop and foliar application micro nutrient 30 and 50 day after sowing and also addition of RDF leading to increase uptake of NPK because of the cumulative effect in increasing growth contributing characters which have been clearly exhibited on the final produce. Similar results were also reported by Meena *et al* (2013), Mostafavi (2012) and Sale *et al* (2017). The significantly lowest total uptake of nitrogen by soybean was observed under the treatment T_1 this might due to lowest available Fe in soil which is below the critical limit and Fe deficiency decrease nodule formation, leghaemoglobin production and nitrogenase activity, leading to low N concentrations (Togay *et al.* 2015).

Table 4.6 Effect of soil and foliar application of iron on nitrogen content and uptake by soybean

Tr. No.	Treatments	Total N		Nitrogen uptake		
		Grain	Straw	Grain	Straw	Total
		---(%)---		----(kg ha^{-1})----		
T_1	Absolute control	4.3	0.70	50.30	11.36	61.66
T_2	GRDF (50:75:45 kg ha^{-1} N: P_2O_5:K_2O + 10 t ha^{-1} FYM)	4.9	0.78	90.74	20.31	111.05
T_3	GRDF + $FeSO_4$ @ 10 kg ha^{-1}	5.0	0.80	92.52	21.69	114.21
T_4	GRDF + $FeSO_4$ @ 20 kg ha^{-1}	5.2	0.79	100.79	22.49	123.28
T_5	GRDF + $FeSO_4$ @ 10 kg ha^{-1} + cow dung slurry @ 500-liter ha^{-1}	5.0	0.82	95.30	22.57	117.87
T_6	GRDF + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	5.1	0.76	95.62	20.97	116.59
T_7	GRDF + $FeSO_4$ @ 10 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	5.1	0.81	100.81	23.01	123.82
T_8	GRDF + $FeSO_4$ @ 20 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	5.2	0.83	109.16	24.52	133.68
	SE$\pm$	0.18	0.03	4.23	1.29	4.83
	CD at 5 %	NS	NS	12.83	3.91	14.67

4.4.2 Phosphorus content and uptake of soybean

The data pertaining to phosphorus content, uptake of grain, straw and total phosphorus uptake by soybean crop as differed by different treatments of soil and foliar sprays of iron are given in Table 4.7 and graphically depicted in Fig 4.10.

From the data in Table 4.7 revealed that phosphorus content in soybean grain and straw was found non-significant effect due to different treatments. The higher P content in grain (0.65%) and straw (0.36%) was noticed in soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent (T_8) followed by treatment T_7 (grain 0.61% and straw 0.34%). The higher P content in grain of soybean was observed as compare to straw of soybean. The higher values of P content in grain and straw were showed in treatments receiving iron either through soil or foliar application alone and its combination along with GRDF over the absolute control (T_1).

The P uptake in grain and straw of soybean was statistically differed due to various treatments. The significantly higher P uptake in grain (13.78 kg ha^{-1}) and straw (10.53 kg ha^{-1}) were noticed in soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent followed by treatment T_7 (grain-11.97 kg ha^{-1} and straw 9.74 kg ha^{-1}). The treatments T_7, T_6, T_5 and T_4 were at par with each other for P uptake in grain of soybean. Whereas treatments T_2 to T_7 were at par with each other for P uptake of straw by soybean. The significantly lowest P uptake of grain (5.90 kg ha^{-1}) and straw (5.43 kg ha^{-1}) of soybean was obtained in treatment without fertilizer.

The control treatment (11.34 kg ha^{-1}) had recorded significantly lowest phosphorus uptake than all other treatments. The maximum total uptake of phosphorus by soybean 24.32 kg ha^{-1} was noted in the treatment soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent which was at par with T_7 (21.72 kg ha^{-1}), T_4 (21.03 kg ha^{-1}) and T_5 (20.99 kg ha^{-1}). Next superior treatment was T_7 (21.72 kg ha^{-1}). It clearly indicated that the better total uptake of phosphorus in soil application of $FeSO_4$ @ 10 and 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent or only soil application of $FeSO_4$ @ 10 and 20 kg ha^{-1} than the rest of treatments.

Thus, the total phosphorus uptake increased with the application of iron through soil application @ 10 and 20 $FeSO_4$ kg ha^{-1} alone and along with two foliar sprays of chelated Fe @ 0.2 per cent. However, the treatments GRDF + two foliar sprays of chelated Fe @ 0.2 per cent recorded significantly lower values of total phosphorus uptake as compare soil application @ 20 $FeSO_4$ kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent. Soil along with foliar application of Fe resulted in enhanced chlorophyll synthesis in leaves leading to increased photosynthesis and ultimately dry matter yield. This has resulted in higher phosphorus uptake by plants and also one of the reason for increased P uptake may be due to the increased dry matter production and synergistic effect between N and P. Further applied Fe to soil or plant might not interfere with P uptake by plants because of the cationic (Fe) and anionic (P) nature absorbed by plants. Das (1996) reported the differential uptake of P and Fe as related to nature of ions. Similar observations were made by Kumar *et al.* (2009) who had reported that the uptake of Fe by grain and straw increased significantly by application of 10 kg Fe ha^{-1} over control in chickpea. Gomaa *et al.* (2015) reported that the mixed foliar application of micronutrient Zn+ Fe significantly increased N, P and K contents and Zn, Fe concentration in wheat grain as compared to the control. The significantly lowest total uptake of phosphorus by soybean was observed under the treatment T_1. This might be due to low P uptake by plants because of low P availability in soils and greater P fixing capacity due to their fine textured nature and calcareousness.

Table 4.7 Effect of soil and foliar application of iron on phosphorus content and uptake by soybean

Tr. No	Treatments	P content		Phosphorus uptake		
		Grain	Straw	Grain	Straw	Total
		---(%)---		----(kg ha^{-1})----		
T_1	Absolute control	0.51	0.30	5.90	5.43	11.34
T_2	GRDF (50:75:45 kg ha^{-1} N: P_2O_5:K_2O + 10 t ha^{-1} FYM)	0.55	0.32	10.51	7.66	18.18
T_3	GRDF+ $FeSO_4$ @ 10 kg ha^{-1}	0.57	0.32	10.21	8.70	18.38
T_4	GRDF+ $FeSO_4$ @ 20 kg ha^{-1}	0.58	0.34	11.37	9.66	21.03
T_5	GRDF+ $FeSO_4$ @ 10 kg ha^{-1} + cow dung slurry @ 500-liter ha^{-1}	0.60	0.35	11.29	9.71	20.99
T_6	GRDF + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	0.60	0.33	11.23	9.16	20.39
T_7	GRDF + $FeSO_4$ @10 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	0.61	0.34	11.97	9.74	21.72
T_8	GRDF + $FeSO_4$ @ 20 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	0.65	0.36	13.78	10.53	24.32
	SE±	0.02	0.03	0.52	0.91	1.20
	CD at 5%	NS	NS	1.59	2.87	3.64

4.4.3 Potassium content and uptake of soybean

The data in respect of potassium content, uptake of grain, straw and total potassium uptake by soybean crop as affected by different treatments of soil application and foliar sprays of iron are presented in Table 4.8 and graphically depicted in Fig 4.11.

From the data in Table 4.8 revealed that the soil application and foliar sprays of iron treatments effect on potassium content in soybean grain and straw was found non-significant. The higher K content in grain (0.96%) and straw (1.61%) was noticed in soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent (T_8) followed by treatment T_7 (grain 0.93% and straw 1.59%). The higher K content in straw was observed as compare to grain of soybean. The treatments receiving iron either through soil or foliar application alone and its combination along with GRDF were noticed higher values of K content in grain and straw over absolute control (T_1).

The K uptake in grain and straw of soybean was statistically differed due to various treatments. The significantly higher K uptake in grain (20.26 kg ha^{-1}) and straw (47.53 kg ha^{-1}) were noticed in soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent as compare to remaining treatments. The treatments T_8 was at with T_7 and T_4 for K uptake of grain by soybean. The treatments T_4 to T_8 were at par with each other for K uptake of grain by soybean. The treatments T_2 to T_7 were at with each other for K uptake of grain and straw of soybean. The treatments T_4 to T_8 were at par with each other for K uptake of grain of soybean. The significantly lowest K uptake in grain (9.92 kg ha^{-1}) and straw (23.40 kg ha^{-1}) of soybean was obtained in treatment without fertilizer over the plot receiving fertilizers.

The highest total uptake of potassium by soybean (67.79 kg ha^{-1}) was recorded under the treatment T_8 (soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2%) which was at par with treatments T_7 (63.70 kg ha^{-1}) and T_4 (62.64 kg ha^{-1}). The total potassium uptake by T_3 (57.41 kg ha^{-1}) was at par with treatments T_2, T_4, T_5 and T_6. It is clearly indicated that the Fe applications, either as soil or foliar application increased the K uptake of soybean. Similar finding also reported by Jawaharlal *et al.* (1988) reported that, soil and foliar application of $FeSO_4$ significantly increased the nitrogen and potassium uptake by onion. The treatment T_2 (55.85 kg ha^{-1}) was at par with treatments T_4, T_5 and T_6 for total potassium uptake by soybean.

The treatments T_8 (soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2%), T_7 (soil application of $FeSO_4$ @ 10 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2%) and T_4 (soil application of $FeSO_4$ @ 20 kg ha^{-1}) were at par with each other indicating that soil application $FeSO_4$ @ 10 and 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent was equivalent to soil application of $FeSO_4$ @ 20 kg ha^{-1} for total potassium uptake by soybean. Treatments receiving soil + foliar spray of Fe noticed higher K content in grain than treatments receiving foliar spray alone. High K content in grain and straw of soybean is attributed to greater uptake of K due to synergistic relation between applied Fe and K (Mortvedt, 1971). Similar results were reported by Pande *et al*. (1993) and Sale *et al.* (2017). The soil application of $FeSO_4$ @ 10 kg ha^{-1} and soil application of $FeSO_4$ @ 10 kg ha^{-1} with cowdung slurry were equivalent with two foliar sprays of chelated Fe @ 0.2 per cent + GRDF and GRDF respectively as regards to the total potassium uptake by soybean. The increase in potassium uptake was attributed to improvement in soil properties and potassium added through FYM. The potassium content of FYM was higher which was helpful for increasing potassium content of soil and due to increased soil potassium and uptake of potassium was also increased in the FYM treatments.

Table 4.8 Effect of soil and foliar application of iron on potassium content and uptake by soybean

Tr. No.	Treatments	K content		Potassium uptake		
		Grain	Straw	Grain	Straw	Total
		---(%)---		----------(kg ha^{-1})--------		
T_1	Absolute control	0.86	1.45	9.92	23.40	33.32
T_2	GRDF (50:75:45 kg ha^{-1} N: P_2O_5:K_2O + 10 t ha^{-1} FYM)	0.89	1.47	16.43	38.23	54.66
T_3	GRDF + $FeSO_4$ @ 10 kg ha^{-1}	0.91	1.49	16.95	40.46	57.41
T_4	GRDF + $FeSO_4$ @ 20 kg ha^{-1}	0.92	1.57	17.98	44.66	62.64
T_5	GRDF + $FeSO_4$ @ 10 kg ha^{-1} + cow dung slurry @ 500-liter ha^{-1}	0.91	1.55	17.26	42.71	59.97
T_6	GRDF+ two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	0.92	1.50	17.30	41.29	58.58
T_7	GRDF+ $FeSO_4$ @ 10 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	0.93	1.59	18.32	45.39	63.70
T_8	GRDF + $FeSO_4$ @ 20 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	0.96	1.61	20.26	47.53	67.79
	SE$\pm$	0.04	0.05	0.89	2.20	2.25
	CD at 5%	NS	NS	2.72	6.68	6.85

4.4.4 Iron content and uptake of soybean

The data in respect of iron content, uptake by grain, straw and total iron uptake by soybean crop as affected by various treatments of soil application and foliar sprays of iron are given in Table 4.9 and graphically depicted in Fig 4.12

The data revealed that iron content in soybean grain and straw was statistically influenced by different treatments. The higher Fe content in grain and straw 462 mg kg^{-1} and 205 mg kg^{-1} was noticed in soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent (T_8) followed by T_7 (grain 455 mg kg^{-1}) and straw (202 mg kg^{-1}) and treatment T_6 (grain 440 mg kg^{-1} and straw 195 mg kg^{-1}) The Fe content in grain was higher as compare to straw of soybean. The higher values of Fe content in grain and straw were recorded in treatments receiving the soil application of $FeSO_4$ @ 10 or 20 kg ha^{-1} along with foliar sprays of chelated Fe @ 0.2 per cent at 30 and 50 DAS alone over the soil application of $FeSO_4$ @ 10 or 20 kg ha^{-1}. The higher Fe content in grain and straw of soybean might be due to increase availability iron content in soil through soil application $FeSO_4$ @ 10 or 20 kg ha^{-1} as well as foliar application iron resulted increase the content and uptake of iron. Similar results are also close in conformity with Hanwate *et al.* (2018) had reported that the foliar application iron increase in iron uptake due to improve the performance of root growth and prevented nutritional disorder and consequently caused increased the uptake of iron. Soil application of 50 kg $FeSO_4$ ha^{-1} significantly increased content and uptake of Fe by chickpea over control (Singh *et al*. 2004).

The Fe uptake in grain and straw of soybean was significantly influenced due to various treatments. The significantly higher Fe uptake in grain (968 g ha^{-1}) and straw (611 g ha^{-1}) were noticed in soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent followed by treatment T_7 (grain 890 g ha^{-1} and straw 579 g ha^{-1}). The treatments T_8 and T_7 were at par with other for Fe uptake in grain and straw of soybean. The significantly lowest Fe uptake in grain (385 g ha^{-1}) and straw (243 g ha^{-1}) of soybean was obtained in treatment without fertilizer.

It was evident that all the treatments significantly differ in increasing the total iron uptake by soybean over control (628 g ha^{-1}).The maximum total uptake of iron by soybean (1579 g ha^{-1}) was observed under the treatment T_8 (soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent at which was at par with T_7 (1469 g ha^{-1}) and T_6 (1362 g ha^{-1}). The treatments T_3 to T_7 were par with each other for total uptake of iron. It clearly indicated that the better total uptake of iron was recorded in soil application of $FeSO_4$ @ 10 or 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent over to GRDF and control.

The increase in uptake of iron may be attributed to higher uptake of Fe due to high dry matter production and its further translocation to grain and straw. Application of iron through soil along with farmyard manure supply chelating agent which helps in maintaining the solubility of micronutrients including iron, in addition organic matter improves soil structure which provided better soil aeration and increases the availability of iron as result increases the uptake of iron by soybean. The results of present investigation are in accordance with findings of Sakal *et al.* (1982) in rice and maize, Basavaraja *et al.* (1995) and Das (2000) in maize.

Table 4.9 Effect of soil and foliar application of iron on iron content and uptake by soybean

Tr. No.	Treatments	Fe content		Fe uptake		
		Grain	Straw	Grain	Straw	Total
		---(mg kg^{-1})---		----(g ha^{-1})----		
T_1	Absolute control	334	148	385	243	628
T_2	GRDF (50:75:45 kg ha^{-1} N: P_2O_5:K_2O + 10 t ha^{-1} FYM)	376	167	689	432	1121
T_3	GRDF + $FeSO_4$ @ 10 kg ha^{-1}	401	178	746	484	1230
T_4	GRDF + $FeSO_4$ @ 20 kg ha^{-1}	405	180	788	515	1303
T_5	GRDF + $FeSO_4$ @ 10 kg ha^{-1} + cow dung slurry @ 500-liter ha^{-1}	403	179	760	494	1254
T_6	GRDF + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	440	195	823	539	1362
T_7	GRDF + $FeSO_4$ @ 10 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	455	202	890	579	1469
T_8	GRDF + $FeSO_4$ @ 20 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	462	205	968	611	1579
	SE$\pm$	17.87	7.94	45.77	46.22	77.49
	CD at 5%	54.21	24.09	138.85	140.21	235.04

4.4.5 Manganese content and uptake of soybean

The data regarding to manganese content, uptake by grain, straw and total manganese uptake by soybean crop as influenced by different treatments of soil application and foliar sprays of iron are presented in Table 4.10 and graphically depicted in Fig 4.13.

The data revealed that there was no significantly difference in due to different treatment manganese content in soybean grain and straw. The higher Mn content in grain and straw (25.54 mg kg^{-1}) and (33.70 mg kg^{-1}) was noticed in soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent (T_8) over the rest of other treatments. The Mn content in straw was numerically higher as compare to grain of soybean. The higher values of Mn content in grain and straw were showed in treatments receiving the soil application of $FeSO_4$ @ 10 or 20 kg ha^{-1} and foliar sprays of chelated Fe @ 0.2 per cent at 30 and 50 DAS alone and its combination along with GRDF over to absolute control (T_1).

The Mn uptake in grain and straw of soybean was significantly influenced due to various treatments. The significantly higher Mn uptake in grain (54 g ha^{-1}) and straw (99 g ha^{-1}) were noticed in soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent followed by treatment T_7 (grain 49 g ha^{-1} and straw 90 g ha^{-1}). The treatments T_8, T_7 and T_4 were at par with other for grain Mn uptake of soybean and treatments T_2 to T_7 were at par with each other for straw Mn uptake of soybean. The significantly lowest Mn uptake in grain (21 g ha^{-1}) and straw (40 g ha^{-1}) of soybean was obtained in control.

It was evident that all the treatments significantly differ in increasing the total Mn uptake by soybean over control (61 g ha^{-1}). The soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent was noticed higher total uptake of Mn (153 g ha^{-1}) and followed by T_7 (138 g ha^{-1}) and T_4 (133 g ha^{-1}). The increase in uptake of manganese may be attributed to higher uptake of Mn due to high dry matter production and its further translocation to grain and straw of soybean. Similar results also reported by conformity with soil or foliar application of Fe and Zn increased the Mn uptake of wheat (Kandoliya and Kunjadia, 2018).

The treatments T_3 to T_7 were at par with each other for total uptake of manganese. From the data, it is clearly indicated that the application of Fe either through soil and foliar sprays of chelated Fe @ 0.2 per cent and its combustions with GRDF were improved the total uptake of manganese by soybean. This might be due to application of iron through soil along with organic matter may also increase the availability of micronutrients by complexation with fulvic acids and can be a source of micronutrients to soil in conditions favourable to their decomposition and high microbial activity.

Table 4.10 Effect of soil and foliar application of iron on manganese content and uptake by soybean

Tr. No.	Treatments	Mn content		Mn uptake		
		Grain	Straw	Grain	Straw	Total
		----(mg kg^{-1})----		----(g ha^{-1})----		
T_1	Absolute control	18.10	25.09	21	40	61
T_2	GRDF (50:75:45 kg ha^{-1} N: P_2O_5:K_2O + 10 t ha^{-1} FYM)	22.98	29.07	42	76	118
T_3	GRDF + $FeSO_4$ @ 10 kg ha^{-1}	23.04	29.12	43	80	123
T_4	GRDF + $FeSO_4$ @ 20 kg ha^{-1}	23.48	29.80	46	87	133
T_5	GRDF + $FeSO_4$ @ 10 kg ha^{-1} + cow dung slurry @ 500-liter ha^{-1}	24.22	32.87	45	90	135
T_6	GRDF + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	23.92	29.77	44	82	126
T_7	GRDF + $FeSO_4$ @ 10 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	24.92	31.77	49	90	139
T_8	GRDF + $FeSO_4$ @ 20 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	25.54	33.70	54	99	153
	SE±	1.27	2.35	2.44	9.18	10.77
	CD at 5%	3.85	7.14	7.40	27.85	32.68

4.4.6 Copper content and uptake of soybean

The data pertaining to copper content, uptake by grain, straw and total copper uptake by soybean crop as differed by different treatments of soil application and foliar sprays of iron are presented in Table 4.11 and graphically depicted in Fig 4.14.

Copper content in soybean grain and straw of soybean were found statistically non-significant effect. The higher Cu content in grain and straw (27.40 mg kg^{-1}) and (14.02 mg kg^{-1}) was noticed in soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent (T_8) over the rest of other treatments. The higher values of Cu content in grain and straw were showed in treatments receiving the soil application of $FeSO_4$ @ 10 or 20 kg ha^{-1} and foliar sprays of chelated Fe @ 0.2 per cent at 30 and 50 DAS alone and its combination along with GRDF over absolute control (T_1).

The Cu uptake in grain and straw of soybean was statistically influenced by various treatments. The significantly lowest Cu uptake in grain (24 g ha^{-1}) and straw (16 g ha^{-1}) of soybean was obtained in treatment without fertilizer. The significantly higher Cu uptake in grain (57 g ha^{-1}) and straw (42 g ha^{-1}) were noticed in soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent followed by treatment T_7 (grain 53 g ha^{-1} and straw 38 g ha^{-1}) as well as the treatment T_6, T_5, T_4 and T_3were at par with other for Cu uptake in grain and straw of soybean.

The treatment receiving soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent was recorded significantly higher total copper uptake by soybean (99 g ha^{-1}) over control (40 g ha^{-1}). The treatments T_4 to T_7 were at par with each other for total uptake of copper by soybean. It is clearly observed that application of Fe to soybean crop either through soil of $FeSO_4$ @ 20 kg ha^{-1} and foliar sprays chelated Fe @ 0.2 per cent increased total uptake of copper by soybean. The increase in uptake of copper may be attributed to higher uptake of Cu due to high dry matter production and its further translocation to grain and straw of soybean. It also might be due to farmyard manure increased availability of nutrients in the soil solution with increase in fertility levels. Uptake of nutrients in fact associated with the metabolic activities of plants and with concentration and distribution of ions in the rhizosphere Pattar *et al.* (1999) in groundnut. Similar results also reported by conformity with soil or foliar application of Fe and Zn increased the Cu uptake of wheat (Kandoliya and Kunjadia, 2018).

Table 4.11 Effect of soil and foliar application of iron on copper content and uptake by soybean

Tr. No.	Treatments	Cu content		Cu uptake		
		Grain	Straw	Grain	Straw	Total
		---(mg kg^{-1})---		-----(g ha^{-1})----		
T_1	Absolute control	21.32	9.44	24	16	40
T_2	GRDF (50:75:45 kg ha^{-1} N: P_2O_5:K_2O + 10 t ha^{-1} FYM)	24.81	10.58	46	27	73
T_3	GRDF + $FeSO_4$ @ 10 kg ha^{-1}	25.64	11.15	48	30	78
T_4	GRDF + $FeSO_4$ @ 20 kg ha^{-1}	26.42	12.56	51	36	87
T_5	GRDF + $FeSO_4$ @ 10 kg ha^{-1} + cow dung slurry @ 500-liter ha^{-1}	26.77	12.40	50	34	84
T_6	GRDF + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	26.56	12.86	49	36	85
T_7	GRDF + $FeSO_4$ @10 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	27.35	13.40	53	38	91
T_8	GRDF + $FeSO_4$ @ 20 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	27.40	14.02	57	42	99
	SE$\pm$	1.91	1.26	3.37	4.88	4.89
	CD at 5%	5.89	3.85	10.23	14.81	14.85

4.4.7 Zinc nutrient content and uptake of soybean

The data in respect of zinc content, uptake of grain, straw and total zinc uptake by soybean crop as influenced by different treatments of soil application and foliar sprays of iron are given in Table 4.12 and graphically depicted in Fig 4.15.

Zinc content in grain and straw of soybean was not statistically differed due to different treatments. The numerically higher Zn content in grain (59 mg kg^{-1}) and straw (26.88 mg kg^{-1}) of soybean was noticed in soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent (T_8) over to other treatments. The Zn content in straw was numerically lower than in grain of soybean. The higher values of Zn content in grain and straw were noticed in fertilizer treatments than absolute control (T_1).

The zinc uptake in grain and straw of soybean was significantly influenced due to different treatments.The significantly higher Zn uptake in grain (124 g ha^{-1}) and straw (80 g ha^{-1}) of soybean were found T_8 and followed by treatment T_7 (grain 113 g ha^{-1} and straw 74 g ha^{-1}). The treatments T_2 to T_7 were equally with each other for Zn uptake in grain and straw of soybean. The significantly lowest Zn uptake in grain (49 g ha^{-1}) and straw (31 g ha^{-1}) of soybean was obtained in treatment without fertilizer.

The treatments of soil application and foliar sprays of iron significantly differ in total zinc uptake by soybean. The maximum total uptake of Zn (204 g ha^{-1}) by soybean was showed under the treatment T_8. The treatments T_2 to T_7 were at par with each other for total uptake of Zn. It clearly indicated that the better total uptake of zinc was increases with soil application of Fe and foliar sprays of chelated Fe @ 0.2 per cent with GRDF. Zn reacts easily with organic chelating agents present in FYM, which can increase crop available Zn in the soil solution. The presence of chelating agents and complexation of Zn by organic matter can increase the availability of Zn in the soil solution. The increase in uptake of Zn may be attributed to higher uptake of Zn due to high dry matter production and its further translocation to grain and straw. Similar results were also reported by Patel *et al.* (2007).

Table 4.12. Effect of soil and foliar application of iron on zinc content and uptake by soybean

Tr. No.	Treatments	Zn content		Zn uptake		
		Grain	Straw	Grain	Straw	Total
		---(mg kg^{-1})---		----(g ha^{-1})-----		
T_1	Absolute control	42.22	18.65	49	31	80
T_2	GRDF (50:75:45 kg ha^{-1} N: P_2O_5:K_2O + 10 t ha^{-1} FYM)	54.71	22.85	101	59	160
T_3	GRDF + $FeSO_4$ @ 10 kg ha^{-1}	54.20	23.40	101	62	163
T_4	GRDF + $FeSO_4$ @ 20 kg ha^{-1}	56.97	25.38	111	73	184
T_5	GRDF + $FeSO_4$ @ 10 kg ha^{-1} + cow dung slurry @ 500-liter ha^{-1}	56.90	25.43	107	70	177
T_6	GRDF + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	57.44	24.93	107	70	177
T_7	GRDF + $FeSO_4$ @ 10 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	58.01	26.33	113	74	187
T_8	GRDF + $FeSO_4$ @ 20 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	59.00	26.88	124	80	204
	SE±	5.99	2.20	12.44	8.31	16.43
	CD at 5%	18.90	6.69	37.73	25.21	49.85

4.5 Effect of soil and foliar application of iron on soil chemical properties after harvest of soybean

The data revealed that the highest residual values of available nitrogen (209 kg ha^{-1}), phosphorus (10.2 kg ha^{-1}), potassium (470 kg ha^{-1}), and DTPA micronutrients iron (4.71 mg kg^{-1}), copper (0.49 mg kg^{-1}), zinc (0.47 mg kg^{-1}), manganese (2.65 mg kg^{-1}) in the soil after the harvest of crop was recorded in soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2% (T_8) at 30 and 50 DAS over rest of treatments.

4.5.1 Soil pH

The data regarding to soil reaction after harvest of soybean as differed by different treatments of soil and foliar sprays of iron are presented in Table 4.13.

The soil pH did not differ significantly by the application of iron through soil or foliar spray although decreased over control. This might be due to high buffering capacity of calcareous soil. The absolute control was found higher pH (8.27) than other remaining treatments. The lower soil pH was observed in (8.10) T_8 and (8.13) T_7 *i.e.* soil application $FeSO_4$ @ 10 and 20 kg ha^{-1} along with two foliar spray of chelated Fe @ 0.2 % at 30 & 50 DAS. The lowest pH of soil (8.07) was obtained in T_6. The higher soil pH was in T_1 (8.27) found as compare to initial pH of soil (8.15). The decrease in pH at harvest was observed in all the treatments receiving with Fe application through soil and foliar spray as compare to initial pH (8.15). This might be due to FYM contains high organic matter which releases organic acids (R-COOH) after decomposition that can reduce soil pH due to H^+ dissociation from carboxyl groups.

4.5.2 Electrical conductivity of soil

The data regarding electrical conductivity of soil after harvest of soybean as differed due to different treatments of soil and foliar sprays of iron are presented in Table 4.13.

Electrical conductivity of soil was found non-significant effect due to various treatments. The soil application $FeSO_4$ @ 20 kg ha^{-1} along with two foliar spray of chelated Fe @ 0.2 per cent at 30 & 50 DAS was recorded higher EC in T_8 (0.24 dS m^{-1}) with equivalent to T_6 (0.24 dS m^{-1}) and T_5 (0.24 dS m^{-1}). The absolute control (T_1) treatment showed numerically higher electrical conductivity in soil. The higher may be EC of soil in soil application $FeSO_4$ @ 20 kg ha^{-1} along with two foliar spray of chelated Fe @ 0.2 per cent at 30 & 50 DAS in (T_8 0.24 dS m^{-1}) was found as compare to initial EC content (0.18 dS m^{-1}).

In general, it was observed that the soil pH and soluble salt content in calcareous soil was not affected by foliar application of iron. The soil pH decreased and EC increase with the increase level of treatments.

4.5.3 Organic carbon content in soil

The data in respect of organic carbon content in soil at harvest as affected due to soil application and foliar spray of iron are presented in Table 4.13.

It is evident from the data given in Table 4.13 showed that the organic carbon content in soil was significantly influenced by various treatments at harvest stage. The organic carbon content (0.53%) in soil at harvest was higher in T_8 as compare to rest of the treatments. The T_8 was at par with all the treatments of soil application $FeSO_4$ @ 10 and 20 kg ha^{-1} alone and along with two foliar spray of chelated Fe @ 0.2 per cent at 30 & 50 DAS, soil application $FeSO_4$ @ 10 kg ha^{-1} with cow dung slurry, two foliar spray of chelated Fe @ 0.2 per cent at 30 & 50 DAS and GRDF except control. The treatments receiving GRDF with Fe application through soil and foliar sprays were increased in soil organic carbon content at harvest stage over to control. It indicated that the application of FYM and chemical fertilizers improves organic carbon content in soil. These findings during experimentation revealed that integration of fertilizers with organic manure was improved the organic carbon status of soil *i.e.* soil health, supported by the findings of Singh *et al.* (1998). The significantly lowest organic carbon content in soil (0.41%) was obtained in absolute control (T_1). The increase in organic carbon content at harvest stage was observed in all the treatments receiving GRDF with Fe application through soil and foliar spray as compare to initial (0.45%) organic carbon content. The soil organic matter with applied levels of Fe alone or in their combination could be associated with greater biomass production and greater roots developments in same treatments. The correlation analysis between soil organic matter and biomass production confirms the same statement. Similar results also reported by (Rahman *et al*. 2008).

4.5.4 Calcium carbonate content in soil

The calcium carbonate in soil was found non-significantly due to various treatments at harvest Table 4.13.

The lowest calcium carbonate content in soil (6.15%) and (6.16%) was obtained in T_7 and T_8. The decrease in percent calcium carbonate content in T_7 (6.15%) was found as compare to initial calcium carbonate content (6.8%). The decrease in calcium carbonate content at harvest stage was observed in all the treatments receiving (T_7) and (T_8) with Fe application through soil and foliar spray as compare to initial calcium carbonate (6.8%). The calcium carbonate in soil was more under T_1 (6.51%) rest of the treatments. The soil application $FeSO_4$ @ 10 and 20 kg ha^{-1} and GRDF in treatments lower calcium carbonate in soil. The decreased calcium carbonate content in soil might be due to solubilization of calcium carbonate by the acids produced during the decomposition of organic matter present in FYM which resulted in reducing the calcium carbonate content of soil.

Table No. 4.13 Effect of soil and foliar application of iron on soil chemical properties after harvest of soybean

Tr. No.	Treatments	pH (1:2.5)	EC (dS m^{-1})	Organic carbon (%)	$CaCo_3$ (%)
T_1	Absolute control	8.27	0.20	0.41	6.51
T_2	GRDF (50:75:45 kg ha^{-1} N: P_2O_5:K_2O + 10 t ha^{-1} FYM	8.10	0.23	0.48	6.31
T_3	GRDF + $FeSO_4$ @ 10 kg ha^{-1}	8.13	0.23	0.52	6.25
T_4	GRDF + $FeSO_4$ @ 20 kg ha^{-1}	8.13	0.23	0.52	6.17
T_5	GRDF + $FeSO_4$ @ 10 kg ha^{-1} + cow dung slurry @ 500-liter ha^{-1}	8.13	0.24	0.49	6.15
T_6	GRDF + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	8.07	0.24	0.47	6.27
T_7	GRDF+ $FeSO_4$ @ 10 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	8.13	0.23	0.51	6.15
T_8	GRDF + $FeSO_4$ @ 20 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	8.10	0.24	0.53	6.16
	Initial	**8.15**	**0.18**	**0.45**	**6.8**
	SE$\pm$	0.06	0.01	0.01	0.09
	CD at 5%	NS	NS	0.05	NS

4.5.5. Available nutrients status in soil

The soil samples were collected at harvest stage of soybean and available nutrient content in soil were analysed.

4.5.5.1 Available nitrogen content in soil

The data pertaining to soil available nitrogen content at harvest as influenced by soil application and foliar spray of iron are given in Table 4.14 and graphically depicted in Fig 4.16.

The available nitrogen content in soil was significantly influenced by various treatments. The available nitrogen content in soil at harvest was significantly more under T_8 (209 kg ha^{-1}) as compare to rest of the treatments. The T_8 was at par with all the treatments of soil application $FeSO_4$ @ 10 and 20 kg ha^{-1} alone and along with two foliar spray of chelated Fe @ 0.2 per cent at 30 & 50 DAS, soil application $FeSO_4$ @ 10 kg ha^{-1} with cow dung slurry, two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS and GRDF except control. The significantly lowest available nitrogen content in soil (146 kg ha^{-1}) was obtained in absolute control (T_1). The decrease in soil available nitrogen content in absolute control (146 kg ha^{-1}) was found as compare to initial soil available nitrogen content (170 kg ha^{-1}). This might be due to more uptake of nitrogen for growth and development of soybean. The increase in soil available nitrogen content at harvest was observed in all the treatments receiving GRDF with Fe application through soil and foliar spray as compare to initial available nitrogen content (170 kg ha^{-1}).

The treatments receiving GRDF with Fe application through soil and foliar sprays showed increase in the soil available nitrogen content at harvest stage over to GRDF only. The increase in available nitrogen might be due to fixation of nitrogen by leguminous crop. Soil and foliar application of Fe increased the available nitrogen content after harvest. This might due to iron play an important role in biological nitrogen fixation in legume crop as well as increase leghaemoglobin content in root nodules which is resulted increase in nitrogen availability in soil. Iron has a syngerstic effect with nitrogen as well as soybean is legume crop which fixes atmosphere nitrogen as well as substantial amount of N remain in root biomass which also responsible for increasing soil available nitrogen content in Fe Fertilized treatments as compare to without applied Fe. Similar results were close in conformity with Hemmati (2005) noted that soil nitrogen increases with direct application of micronutrients on soil or foliar application. Mostafavi (2012) also noticed that application of Fe either through soil or foliar along with a RDF leading to increase the available N content in soil.

4.5.5.2 Available phosphorus content in soil

The available phosphorus content in soil was significantly influenced by soil application and foliar spray of iron at harvest Table 4.14 and graphically depicted in Fig 4.17.

The available phosphorus content in soil was significantly higher in T_8 (10.2 kg ha^{-1}) over rest of the treatments at harvest. The treatments from T_2 to T_8 were similar for phosphorus content in soil at harvest. It clearly indicated that all treatments GRDF and GRDF along with Fe were significantly superior over the unfertilized control.

The significantly lowest available phosphorus content in soil (7.0 kg ha^{-1}) was obtained in absolute control (T_1). The decrease in soil available phosphorus content in absolute control (7.0 kg ha^{-1}) was found as compare to initial available phosphorus content (7.5 kg ha^{-1}) this might be due to absorption of phosphorus for growth and development of soybean. The increase in soil available phosphorus content at harvest stage was observed in all the treatments receiving GRDF with Fe application through soil and foliar spray as compare to initial available phosphorus content (7.5 kg ha^{-1}). It clearly indicated that soil application of micronutrients significantly increased the available phosphorus content after harvest of the crop. It indicated that the available phosphorus content in soil increased due to PSB inoculation to soybean seed which might be due to mineralisation and solubilization of inorganic fixed soil phosphorus by organisms as well as FYM has also source of organic matter as a energy for enhancing growth of micro organisms and FTM also contain phosphorus and Fe had role in chlorophyll synthesis and also increasing root biomass with the growth parameters of soybean. Similar finding also reported by (Abbas *et al*. 2009), the application of Fe increased P their concentration in soil significantly over control. Rahman *et al*. (2008) noticed that the possible reason could be that a large part of the soil adsorbed P has been taken up by the crop due to increased efficiency of Fe and Mo leaving behind the strongly adsorbed P (2.18 mg kg^{-1}) at soil content nearly at par to its native level (2.45 mg kg^{-1}).

4.5.5.3 Available potassium content in soil

The data regarding soil available potassium content at harvest as affected by the soil application and foliar spray of iron are given in Table 4.14.

It is evident from the data presented in Table 4.14 showed that there was no significant difference in available potassium content in soil due to various treatments. The probable reason for these statistically non-significant in differences may be that the test soil might have contained sufficient K and as a results removal of K in plant biomass had little influence on the residual K content (Rahman *et al*., 2008).

The available potassium content in soil at harvest was more under T_8 (470 kg ha^{-1}) over rest of the treatments. The treatments receiving GRDF along with Fe application through soil and foliar sprays were numerically higher in soil available potassium content at harvest stage than GRDF only. The rating for soil available potassium is very high (470 kg ha^{-1}) as per six tier system.

The lowest available potassium content in soil (414 kg ha^{-1}) was recorded in absolute control treatment (T_1). The decrease in soil available potassium content in absolute control (414 kg ha^{-1}) was found as compare to initial available potassium content (433 kg ha^{-1}) this might be due to more utilization of potassium for growth and development of soybean. The increase in soil available potassium content at harvest stage was observed in all the treatments receiving GRDF with Fe application through soil and foliar spray as compare to initial available potassium content (433 kg ha^{-1}). The increase in potassium content in soil might be due to application of FYM along with K fertilizer application as well as potassium have syngerstic effect with as iron. Similar results were also reported by Mortvedt *et al.* (1972) noted that the application of Fe to soil and plant in reuse in K in soil cause synergistic relationship between K and Fe.

Table 4.14 Effect of soil and foliar application of iron on soil available N, P and K after harvest of soybean

Tr. No	Treatments	Soil available nutrients (kg ha^{-1})		
		N	P	K
T_1	Absolute control	146	7.0	414
T_2	GRDF (50:75:45 kg ha^{-1} N: P_2O_5:K_2O + 10 t ha^{-1} FYM	192	9.2	459
T_3	GRDF + $FeSO_4$ @ 10 kg ha^{-1}	197	9.4	467
T_4	GRDF + $FeSO_4$ @ 20 kg ha^{-1}	201	9.6	463
T_5	GRDF + $FeSO_4$ @ 10 kg ha^{-1} + cow dung slurry @ 500-liter ha^{-1}	205	9.6	459
T_6	GRDF + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	197	9.2	467
T_7	GRDF+ $FeSO_4$ @ 10 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	201	9.8	463
T_8	GRDF + $FeSO_4$ @ 20 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	209	10.2	470
	Initial	**170**	**7.5**	**433**
	SE$\pm$	9.76	0.45	16.93
	CD at 5%	29.62	1.38	NS

4.5.5.4 DTPA iron content in soil

The data in respect to DTPA Fe content at harvest stage as differed by soil application and foliar spray of iron are presented in Table 4.15 and graphically depicted in Fig 4.18.

The DTPA Fe content in soil was differed significantly due to various treatments. The treatment T_8 was recorded significantly more DTPA Fe content under (4.71 mg kg^{-1}) in soil at harvest over rest of the treatments. The T_8 was at par with all the treatments of soil application $FeSO_4$ @ 10 and 20 kg ha^{-1} alone and along with two foliar spray of chelated Fe @ 0.2 per cent at 30 & 50 DAS, soil application $FeSO_4$ @ 10 kg ha^1 with cow + dung slurry @ 500 liter ha^{-1} as well as soil application $FeSO_4$ @ 10 kg ha^{-1} GRDF except control. The treatments receiving GRDF with Fe application through soil and foliar sprays were increased in soil DTPA Fe content at harvest stage over to control. Similar results close in accordance with Farid Hellal (2004) reported that the soil application of 50 kg ferrous sulphate ha^{-1} with 1 per cent foliar spray of ferrous sulphate and 10 t FYM ha^{-1} recorded higher (5.04 mg kg^{-1}) DTPA-extractable iron over control (3.27 mg kg^{-1}) after harvest of groundnut.

The significantly lowest DTPA Fe content in soil (4.17 mg kg^{-1}) was obtained in absolute control treatment (T_1). The decrease in soil DTPA Fe content was found in absolute control (4.17 mg kg^{-1}) as compare to initial DTPA Fe content (4.05 mg kg^{-1}), this might be due to extraction of iron for growth and development of soybean. The increase in soil Fe content was observed above critical limit (4.5 mg kg^{-1}) at harvest stage in all the treatments receiving GRDF with Fe application through soil and foliar spray as compare to initial DTPA iron content (4.05 mg kg^{-1}) and it clearly indicated that improvement of DTPA Fe content in soil due to application of Fe. This might be due to soil applied iron forms a chelating agent with applied farmyard manure that helps in keeping micronutrient (Fe) soluble and consequently more available to the plants for longer period (Manna *et al.*, 1978).

4.5.5.5 DTPA zinc content in soil

The DTPA Zn content in soil was found non-significant due to soil application and foliar spray of iron (Table 4.15). The DTPA zinc content in soil at harvest was higher under T_8 (0.47 mg kg^{-1}) over the other treatments. The soil application $FeSO_4$ @ 10 and 20 kg ha^{-1}along with foliar spray of chelated Fe @ 0.2 per cent at 30 & 50 DAS was higher Zn in comparison to soil application $FeSO_4$ @ 10 and 20 kg ha^{-1} for soybean crop. The DTPA treatments receiving GRDF with Fe application through soil and foliar sprays were increased in soil Zn content at harvest stage over to control only. The lowest DTPA Zn content in soil (0.32 mg kg^{-1}) was obtained in absolute control (T_1). The over DTPA Zn content in absolute control (0.32 mg kg^{-1}) was found over to initial DTPA Zn content (0.35 mg kg^{-1}) this might be due to uptake of Zn for growth and development of soybean. The increase in soil DTPA Zn content at harvest stage was observed in all the treatments receiving GRDF with Fe application either through soil and foliar spray as compare to initial DTPA Zn content (0.35 mg kg^{-1}). The higher availability of Zn in soil due to application of FYM could be ascribed to mineralization of manures, reduction in fixation and complexing properties of decomposition products of manures with micronutrients (Raddy and Raddy, 1998).

4.5.5.6 DTPA manganese content in soil

It is evident from the data given in Table 4.15 that the DTPA Mn content in soil was not significantly influenced due to soil application and foliar spray of iron. The DTPA Mn content in soil at harvest was higher under T_8 (2.65 mg kg^{-1}) than the other treatments. The DTPA Mn content in all treatments are numerically higher than absolute control. The soil application $FeSO_4$ @ 10 and 20 kg ha^{-1} was observed higher DTPA Mn in GRDF as compare to control. The treatments receiving GRDF with Fe application through soil and foliar sprays were numerically higher in soil DTPA manganese content at harvest stage over to GRDF only.

The lowest DTPA Mn content in soil (2.42 mg kg^{-1}) was obtained in absolute control treatment (T_1). The decrease in soil DTPA Mn content in absolute control (2.42 mg kg^{-1}) was found as compare to initial DTPA Mn content (2.52 mg kg^{-1}), this might be due to more uptake of Mn for growth and development of soybean. The increase in soil DTPA Mn content at harvest stage was observed in all the treatments receiving GRDF with Fe application through soil and foliar spray as compare to initial DTPA Mn content (2.52 mg kg^{-1}). The improvement may also be attributed to the release of native micronutrients contained in the FYM as a consequence of microbial decomposition (Jarecki,1991).

4.5.5.7 DTPA copper content in soil

The data pertaining to DTPA Cu content at harvest as influenced by the soil application and foliar spray of iron are given in Table 4.15.

The DTPA Cu content in soil was not significantly influenced due to various treatments. The DTPA Cu content in soil at harvest was more under T_8 (0.49 mg kg^{-1}) than other treatments. The soil application $FeSO_4$ @ 10 and 20 kg ha^{-1} recorded more DTPA Cu than control. The treatments receiving GRDF with Fe application through soil and foliar sprays were increased in soil DTPA Cu content at harvest stage over to GRDF only. The DTPA Cu content in all treatments were numerically higher than absolute control. The significantly lowest DTPA Cu content in soil (0.35 mg kg^{-1}) was obtained in absolute control treatment (T_8). The decrease in soil DTPA Cu content in absolute control (0.35 mg kg^{-1}) was found as compare to initial DTPA Cu content (0.40 mg kg^{-1}). The increase in soil DTPA Cu content at harvest stage was observed in all the treatments receiving GRDF with Fe application through soil and foliar spray as compare to initial DTPA Cu content (0.35 mg kg^{-1}). This might be due to FYM increased the Cu content by supplying complexing agents, which formed stable complexes with Cu micronutrients. Organometallic complexes reduce the adsorption, fixation and precipitation of these metals in the soil. These results are in conformity with those reported by Jalali *et al.* (1990) and Kumar *et al.* (2000).

Table. 4.15 Effect of soil and foliar application of iron on soil DTPA micronutrient after harvest of soybean

Tr. No.	Treatments	Soil DTPA micronutrients ($mg\ kg^{-1}$)			
		Fe	**Mn**	**Cu**	**Zn**
T_1	Absolute control	4.17	2.42	0.35	0.32
T_2	GRDF (50:75:45 kg ha^{-1} N: P_2O_5:K_2O +10 t ha^{-1} FYM	4.52	2.48	0.38	0.38
T_3	GRDF+ $FeSO_4$ @ 10 kg ha^{-1}	4.56	2.51	0.40	0.40
T_4	GRDF+ $FeSO_4$ @ 20 kg ha^{-1}	4.65	2.58	0.41	0.42
T_5	GRDF+ $FeSO_4$ @ 10 kg ha^{-1} + cow dung slurry @ 500-liter ha^{-1}	4.59	2.59	0.43	0.43
T_6	GRDF+ two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	4.54	2.55	0.42	0.42
T_7	GRDF+ $FeSO_4$ @ 10 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	4.67	2.63	0.45	0.45
T_8	GRDF + $FeSO_4$ @ 20 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	4.71	2.65	0.49	0.47
	Initial	**4.05**	**2.52**	**0.40**	**0.35**
	SE$\pm$	0.19	0.15	0.07	0.04
	CD at 5%	0.59	NS	NS	NS

4.6 Effect of soil and foliar application of iron on iron use efficiency

The data regarding to iron use efficiency of soybean as influenced by soil and foliar application of iron are presented in Table 4.16.

The higher iron use efficiency (76.34 kg kg^{-1}) was noticed in soil application $FeSO_4$ @ 20 kg ha^{-1} along with two foliar spray of chelated Fe @ 0.2 per cent at 30 and 50 DAS (T_8) 76.34 kg kg^{-1} treatments as compare to remaining treatments. Next to T_8, the soil application $FeSO_4$ @ 10 kg ha^{-1} along with two foliar spray of chelated Fe @ 0.2 per cent at 30 and 50 DAS (T_7) 65.45 kg kg^{-1}, $FeSO_4$ @ 20 kg ha^{-1} (T_4) 35.26 kg kg^{-1} and $FeSO_4$ @ 10 kg ha^{-1} (T_3) 16.84 kg kg^{-1} were higher over to GRDF. As increases the doses of $FeSO_4$ increased iron use efficiency in soybean and vice versa.

Table. 4.16 Effect of soil and foliar application of iron on Fe use efficiency of soybean

Tr. No.	Treatments	Fe use efficiency (kg kg^{-1})
T_1	Absolute control	00
T_2	GRDF ((50:75:45 kg ha^{-1} N: P_2O_5: K_2O + 10 t ha^{-1} FYM	00
T_3	GRDF + $FeSO_4$ @ 10 kg ha^{-1}	16.84
T_4	GRDF + $FeSO_4$ @ 20 kg ha^{-1}	35.26
T_5	GRDF + $FeSO_4$ @ 10 kg ha^{-1} + cow dung slurry @ 500-liter ha^{-1}	30.00
T_6	GRDF + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	00
T_7	GRDF + FeSO4 @ 10 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	65.45
T_8	GRDF + $FeSO_4$ @ 20 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2% at 30 & 50 DAS	76.34

4.7. Effect of soil and foliar application of iron on economics of soybean.

The data regarding to economics of soybean as influenced by soil and foliar application of iron are presented in Table 4.17 and graphically depicted in Fig 4.19.

The highest B:C ratio, net returns obtained with soil application and foliar soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent at 30 and 50 DAS. T_8 was recorded significantly higher net returns (Rs.29781) and B: C ratio (1.52). While, among foliar spray of iron sulphate @ 0.2 per cent might be due to significant increase in yield with increased supply of available iron in the soil and correction in hidden deficiency of ferrous in plants or better nutrition of the crop with foliar application of these micronutrients.

The T_8 was at par with the treatments of soil application $FeSO_4$ @ 10 kg ha^{-1} along with two foliar spray of chelated Fe @ 0.2 per cent at 30 & 50 DAS and soil application $FeSO_4$ @ 20 kg ha^{-1} for net returns from soybean. The absolute control lower net returns (Rs.11897) and B: C ratio (1.33) but remaining treatments higher numerically net returns and B:C ratio. The higher net monetary returns were noticed in T_8 due to more yield and growth of soybean. These results are in conformity with those reported by Billore *et al.* (2005).

Table 4.17 Effect of soil and foliar application of iron on economics of soybean

Tr. No.	Treatment	Gross returns (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
T_1	Absolute control	48018	36121	11897	1.33
T_2	GRDF (50:75:45 kg ha^{-1} N: P_2O_5:K_2O + 10 t ha^{-1} FYM)	76296	56519	19777	1.35
T_3	GRDF + soil application $FeSO_4$ @ 10 kg ha^{-1}	77410	56639	20772	1.37
T_4	GRDF + soil application $FeSO_4$ @ 20 kg ha^{-1}	80979	56759	24220	1.43
T_5	GRDF + $FeSO_4$ @ 10 kg ha^{-1} + cow dung slurry @ 500 litter ha^{-1}	78311	56764	21548	1.38
T_6	GRDF + two foliar sprays of chelated Fe @ 0.2% at 30 and 50 DAS	77659	57219	20441	1.36
T_7	GRDF + soil application of $FeSO_4$ @ 10 kg ha^{-1} + two foliar sprays of chelated Fe @ 0.2% at 30 and 50 DAS.	81335	57339	23996	1.42
T_8	GRDF + soil application of $FeSO_4$ @ 20 kg ha^{-1} + two foliar sprays of chelated Fe @ 0.2% at 30 and 50 DAS.	87239	57459	29781	1.52
	S.E.$\pm$	-	-	2446	-
	C.D. at 5%	-	-	7419	-

Rate of Urea Rs. 6.19 kg^{-1}, Single super phosphate Rs. 8.0 kg $^{-1}$, Muriate of potash Rs.16.8 kg $^{-1}$,

FYM- Rs. 1,200 t^{-1}, cow dung Rs.1 kg $^{-1}$, soybean seed Rs. 3500 q $^{-1}$, ferrous sulphate-Rs.12 kg^{-1}, Fe-EDTA- Rs. 350 kg $^{-1}$

5. SUMMARY AND CONCLUSIONS

The present investigation was undertaken with view to field experiment was conducted to study the effect of soil and foliar application of iron on nutrient availability, uptake, yield and quality of soybean (*Glycine max.*L.) variety *Phule Sangam* in Inceptisol during *kharif*, 2018 at Agricultural Research Station, Kasbe Digraj, Dist: Sangli (MS). The experiment was laid out in randomized block design with eight treatments and replicated thrice. The experimental soil was alkaline, calcareous, clay in texture, low in available nitrogen, phosphorus, very high in available potassium and iron deficient. The salient findings of the investigation are as follows.

5.1 Summary

5.1. Growth parameters of soybean

The soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2% (T_8) recorded the significantly higher chlorophyll content at 30 and 50 DAS (20.28 mg g^{-1}) and (21.95 mg g^{-1}), average number of days to 50 per cent flowering (44.33), plant height (86.33 cm), number of branches (11.00 $plant^{-1}$), number of pods (44.00 $plant^{-1}$) and number of effective root nodules (44.33) over the rest of the treatments. The treatment T_8 was at par with T_7 for chlorophyll (19.49 mg g^{-1}) and T_4 (21.15 mg g^{-1}). The chlorophyll content in leaves at 50 DAS recorded higher than at 30 DAS. The treatment T_8 was at par with T_7 (43.66) average number of days to 50 per cent flowering. The treatments T_2 to T_7 were at par with each other for average number of days to 50 per cent flowering, T_7 (85.00 cm), T_4 (83.33 cm) and T_6 (84.00 cm) for plant height, T_7 (10.66 $plant^{-1}$),T_4 (10.00 $plant^{-1}$) of T_6 (10.00 $plant^{-1}$) and T_5 (9.66 $plant^{-1}$) for number of branches, T_7 (43.33 $plant^{-1}$) and T_4 (41.33 $plant^{-1}$) for number of pods and T_7, T_4 for number of effective root nodules. It clearly indicated that basal application $FeSO_4$ @ 10 or 20 kg ha^{-1} with two foliar sprays of chelated Fe @ 0.2% were increased growth parameters of soybean.

5.2 Yield and quality parameters of soybean

The significantly higher grain and straw yield (24.93 q ha^{-1} and 37.79 q ha^{-1}) was obtained in soil applied of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2% (T_8) as compare to rest of the treatments. The per cent increasing in grain and straw yield by treatment T_8 was 14% & 14% over GRDF treatment and 81%, 54% over the control, respectively. The T_8 was at par with T_7 (23.24 q ha^{-1}) and T_4 (23.14 q ha^{-1}) for grain yield. The treatment GRDF (T_2) was at par with treatments T_3 to T_7 for grain yield of soybean. The treatment T_8 was at par with T_3 (34.79 q ha^{-1}) to T_7 (36.38 q ha^{-1}) regarding straw yield of soybean. The treatment T_8 recorded the significantly higher 100 grain weight (19.20 g) as compare to rest of the treatments. The oil content in seed was not influenced significantly due to various treatments. However, the oil yield was significantly influenced by various treatments. The soil application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated

Fe @ 0.2% recorded the significantly higher oil content (19.46%) and oil yield (485 kg ha^{-1}) over the rest of treatments. The significantly higher crude protein (29.60%) and crude protein yield (737 kg ha^{-1}) was noticed in T_8 as compare to rest of the treatments. The treatments T_2 to T_7 were at par with each other for crude protein content in soybean and T_7 (681 kg ha^{-1}) and T_4 (681 kg ha^{-1}) for crude protein yield of soybean.

5.3. Nutrient content and uptake of soybean

The nitrogen, phosphorus and potassium content in grain and straw of soybean was not statistically influenced by soil application and foliar sprays of Fe. The N, P and K uptake in grain and straw and total N, P and K uptake of soybean was significantly affected due to soil application and foliar sprays of Fe treatments. The maximum total uptake of nitrogen (133.68 kg ha^{-1}), phosphorus (24.32 kg ha^{-1}) and potassium (67.79 kg ha^{-1}) by soybean was observed under T_8 and it was at par with T_7 (123.82 kg ha^{-1}) and T_4 (123.28 kg ha^{-1}) for total uptake of nitrogen, T_7 (21.72 kg ha^{-1}), T_4 (21.03 kg ha^{-1}) and T_5 (20.99 kg ha^{-1}) for total uptake of phosphorus and T_7 (63.70 kg ha^{-1}) ,T_4 (62.64 kg ha^{-1}) for total potassium uptake of soybean.

The iron content, uptake by grain, straw and total iron uptake by soybean crop was statistically influenced by soil application and foliar sprays of iron. However, Mn, Cu and Zn content of soybean in grain and straw was found non significant effect but Mn, Cu and Zn uptake in grain, straw and Mn, Cu, Zn total uptake of soybean was significant effect as influenced by different treatments. The maximum total uptake of Fe by soybean (1579 g ha^{-1}), Mn (153 g ha^{-1}), Cu (99 g ha^{-1}) and Zn (204 g ha^{-1}) were noticed under T_8. The treatment T_8 was at par with T_7 (1469 g ha^{-1}) and T_6 (1362 g ha^{-1}) for total uptake of Fe, T_7 (139 g ha^{-1}) and T_4 (133 g ha^{-1}) for total uptake of Mn. The treatments T_4 to T_7 and T_2 to T_7 were at par with each other for total uptake of Cu and Zn by soybean, respectively.

5.4. Chemical properties of soil at harvest

5.4.1 Soil pH, electrical conductivity, organic carbon and calcium carbonate

The soil pH and electrical conductivity organic carbon and calcium carbonate and calcium carbonate did not differ significantly by the application of iron through soil or foliar spray although decreased over control. This might be due to high buffering capacity of calcareous soil. The absolute control noticed higher pH (8.27) than other treatments. The soil pH decreased and EC increase with the increase level of Fe treatments. The organic carbon content in soil was significantly influenced by various treatments at harvest stage. The organic carbon content (0.53%) in soil at harvest was higher in T_8 as compare to rest of the treatments. The T_8 was at par with all the treatments except control for soil organic carbon content. The lowest calcium carbonate content in soil (6.15%) and (6.16%) was obtained in T_7 and T_8.

5.5.2 Available nutrients status in soil

The soil available nitrogen and phosphorus content was found significant effect and available potassium content non-significant effect due to soil application and foliar spray of Fe treatments. The available nitrogen and phosphorus content in soil at harvest was significantly more under T_8 as compare to rest of the treatments. However, the treatment T_8 was at par with all the treatments of application Fe alongwith GRDF except control for available nitrogen and phosphorus content and improved status available nitrogen, phosphorus and potassium content in soil. The DTPA Fe content in soil was differed significantly as differed by soil application and foliar spray of iron. Whereas, DTPA Zn, Cu and Mn content in soil was found non-significant. The treatment T_8 was recorded significantly more DTPA Fe content (4.71 mg kg^{-1}) in soil at harvest over rest of the treatments. The T_8 was at par with all the treatments of applied Fe through soil and foliar spray alongwith GRDF except control. The treatments receiving GRDF with Fe application through soil and foliar sprays recorded increased soil DTPA Fe, Zn, Cu and Mn content at harvest stage over control. The increase in soil Fe content was observed above critical limit (4.5 mg kg^{-1}) at harvest stage in all the treatments receiving GRDF with Fe application over initial DTPA iron content (4.05 mg kg^{-1}).

5.5 Iron use efficiency and economics of soybean

The higher iron use efficiency (76.34 kg kg^{-1}) was noticed in GRDF+ $FeSO_4$ @ 20 kg ha^{-1} + two foliar spray of chelated Fe @ 0.2 per cent at 30 & 50 DAS treatments as compare to rest of the treatments $FeSO_4$. As increases the doses of $FeSO_4$ increased iron use efficiency in soybean and vice versa. The treatment T_8 was received significantly higher net returns (Rs.29781) and B:C ratio (1.52) of soybean. The T_8 was at par with the treatments T_7 and T_4 for higher net returns (Rs.23996 and Rs.24220) from soybean.

5.2 Conclusions

1. The basal application of $FeSO_4$ @ 10 or 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2 per cent at 30 and 50 days after sowing improved growth parameters of soybean *viz;* chlorophyll content, average number of days to 50 per cent flowering, plant height, number of branches, number of pods and effective root nodules as compare to only soil application or foliar spray of iron.
2. Significantly higher grain yield (24.93 q ha^{-1}), straw yield (37.79 q ha^{-1}) and 100 grain weight (19.2 g) of soybean was obtained in soil applied of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2% at 30 and 50 days after sowing. The percent increasing in grain and straw yield by treatment T_8 was 14% and 14% over GRDF treatment and 81%, and 54% over the control, respectively.

3. The quality parameters *viz;* oil and crude protein yield of soybean was enhanced due to soil applied of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2% as compare to GRDF and absolute control.
4. The maximum total N, P, K, Fe, Mn, Cu and Zn uptake of soybean were noticed under basal application of $FeSO_4$ @ 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2% at 30 and 50 days after sowing which is equivalent with basal application of $FeSO_4$ @ 10 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2% at 30 and 50 days after sowing.
5. The soil available N, P, DTPA Fe content was exhibited significant effect and available potassium DTPA Zn, Cu and Mn content non-significant effect due to soil application and foliar spray of Fe treatments. The improvement in soil Fe content was observed above critical limit (4.5 mg kg^{-1}) at harvest stage in all the treatments receiving GRDF with Fe application over initial DTPA iron content (4.05 mg kg^{-1}).
6. Iron use efficiency (76.34 kg kg^{-1}) was higher noted in soil application $FeSO_4$ @ 20 kg ha^{-1} along with two foliar spray of chelated Fe @ 0.2% at 30 and 50 DAS as compare to remaining treatments.
7. More net returns from soybean was received due to basal application of $FeSO_4$ @ 10 or 20 kg ha^{-1} along with two foliar sprays of chelated Fe @ 0.2% at 30 and 50 days after sowing.

It can be concluded from the study that the application of 50:75:45 $N:P_2O_5:K_2O$ kg ha^{-1} + 10 t FYM ha^{-1} and soil application of $FeSO_4$ @ 20 kg ha^{-1} alongwith two foliar sprays of chelated Fe @ 0.2% at 30 and 50 DAS to soybean in iron deficient soil recorded higher growth parameters, yield, quality parameters, nutrient uptake and net monetary returns and B:C ratio. The residual soil fertility was improved in treatments received GRDF alongwith Fe as compare to initial soil fertility status.

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7. VITAE

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MASTER OF SCIENCE (AGRICULTURE)

IN

SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

2019

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