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Impact of different sources and levels of iron on yield and quality of groundnut

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Abstract
An experiment was conducted to study the "Impact of different sources and levels of iron on yield and quality of groundnut [*Arachis hypogaea* (L.)]." at Mangulam village of Mangalor block, Cuddalore district, Tamil Nadu. Total eleven treatments were tried in Randomized Block Design (RBD) with three replications. The treatment consisted of different sources and levels of Fe. Soil application of 50 kg Fe-EFYM along with *Bacillus subtilis* @ 2 kg ha^{-1} and RDF (T_7) recorded significantly the higher number of pods per plant (38.67), 100 kernel weight (48.69 g), pod yield (2060 kg ha^{-1}), haulm yield (2891 kg ha^{-1}), oil yield (966 kg ha^{-1}) and protein content (14.5%) followed by soil application of 37.5 kg Fe-EFYM along with *Bacillus subtilis* @ 2 kg ha^{-1} and RDF (T_6). It was also observed that, the oil content was not influenced due to soil and foliar applied iron treatment alone or in combinations.

Keywords: Iron, Fe-EFYM, *Bacillus subtilis*, groundnut

Introduction

At global level, groundnut is the fourth-most significant oil seed crop in the world and the greatest source of edible oil in the world and ranks 13th among all food crops. India is the top groundnut producer in the world, accounting for around 38% of global production.

In India, groundnut accounts for 40% of the total oilseed acreage and 60% of the production. The groundnut seed (kernel) has 44-50% oil content, 26% protein content, and 10-20% carbohydrate content. Vitamin E, calcium, phosphorus, magnesium, zinc, iron, riboflavin, thiamine, and potassium are all present in good amounts in groundnut seeds. The oil that is produced from the kernel is used for cooking. The remaining oil cake, or residual material, can be utilised as manure since it includes 7 to 8% N, 1.5% P_2O_5, and 1.2% K_2O.

In modern agriculture, the intensification of cropping systems with high yielding varieties, increased use of fertilizers, and concerns over the use of bulk manures resulted in a greater loss of micronutrients in the soil, which in-turn decreased the crop productivity. Since the adoption of modern agricultural technologies and high level usage of NPK fertilisers, coupled with typically free of micronutrients, intensive cultivation of high yielding varieties with more irrigation facilities, limited use of organic matter, and limited recycling of crop residues (Prasad, 1999) [7] micronutrient deficiencies in Indian soils and crops have increased.

The availability and efficiency of micronutrients can be increased by combining inorganic salts of those elements with various organic substances. Numerous substances, including humic acid, fulvic acid, and biological components like organic acid, amino acids, and polyphenols, are produced during the decomposition of organic manures and they act as chelating agents, forming stable complexes with native micronutrients and preventing the precipitation, fixation, oxidation, and leaching of additional inorganic micronutrients. This increases the effectiveness of available and externally applied micronutrients. Micronutrient enriched with organics increases the quality of organics and significantly decreases the amount of application of both inorganic chemicals and organics. According to study report, adding enriched organics in smaller amounts had analogous effects on soil characteristics as adding large amounts without enrichment. The enhanced organics are anticipated to have a longer-lasting positive impact on plant growth.

Even though iron is not a component of chlorophyll, it is important in its production. Iron is a component of several metabolically active substances, including cytochromes (B, B6, C1, and A3), heme and non-heme enzymes, and other functional metal proteins including ferrodoxin and haemoglobin. Iron's catalytic role in biological oxidation-reduction and other metabolic processes in plants, such as oxidative photophosphorylation during cell respiration, is its most well-known activity. It has also been linked to the metabolism of carbohydrates. In an experiment carried out by Yadav (2009) in Bikaner, it was found that increasing $FeSO_4$ level up to 50 kg ha^{-1} enhanced nutrient Fe content and nutrient uptake (N, P, S, and Fe) in kernels, haulms, and shells, as well as protein content in groundnut kernels.

Iron is least soluble in the pH range of 7.4 to 8.5, which is the primary characteristic of calcareous soils, and is therefore greatly influenced by pH (Loeppert and Hallmark, 1985) [5]. High quantities of total Fe may be present in calcareous soils; however they are in unavailable forms. In calcareous soil, numerous plant frequently exhibit visible Fe deficiency or Fe chlorosis. The degree of chlorosis is not always correlated with leaf Fe concentrations, though, because of the nature and causes of Fe chlorosis. Iron concentrations in chlorotic plants can be higher or lower than in healthy plants. Only soils with a pH between 5.5 and 6.0 can support this level of soluble Fe when using inorganic iron.

Iron deficiency is the most prevalent micronutrient deficiencies, which have a negative impact on nutrient quality and crop productivity. Application of enhanced Fe may raise the yield of groundnut and improve the efficiency of fertiliser use. But there is lack of information about how organic materials enriched in iron impact in groundnut. In this line, the present study was conducted to determine the impact of different sources and levels of iron on yield and quality of groundnut.

Materials and Methods

The experiment was conducted in calcareous soil at Mangulam village under Mangalur Block of Cuddalore district, Tamil Nadu. One of the major objectives of the study was to find the effect of different sources and levels of iron on yield and quality of groundnut. The initial soil analytical report (Table 1) of experimental field soil showed the following, the soil was silty clay with pH 8.35 and electrical conductivity of 0.82 dSm^{-1}. The organic carbon status was found to be low with the cation exchange capacity of 34.5 (c mol (p+) kg^{-1}). The fertility status was found to be low in available nitrogen (257.6 kg ha^{-1}), medium in available phosphorus (15.6 kg ha^{-1}) and high in available potassium (336 kg ha^{-1}). The available iron status of the soil was 5.28 mg kg^{-1} which is below their critical level. There were eleven treatments replicated thrice with the plot size of 20 m^2. The treatment details are T_1: RDF (25:50:75 NPK kg ha^{-1}), T_2: RDF + $FeSO_4$ @ 50 kg ha^{-1}, T_3: RDF + Fe-EFYM @ 37.5 kg ha^{-1}, T_4: RDF + Fe-EFYM@50 kg ha^{-1}, T_5: RDF + $FeSO_4$ @ 50 kg ha^{-1} + *Bacillus subtilis* @ 2 kg ha^{-1}, T_6: RDF + Fe-EFYM @ 37.5 kg ha^{-1} + *Bacillus subtilis* @ 2 kg ha^{-1}, T_7: RDF + Fe-EFYM @ 50 kg ha^{-1} + *Bacillus subtilis* @ 2 kg ha^{-1}, T_8: RDF + Fe-EDDHA @ 5 kg ha^{-1} + FS of 1% $FeSO_4$ (30, 40 & 50 DAS), T_9: RDF + FS of 1% $FeSO_4$ (30, 40 & 50 DAS), T_{10}: RDF + FS of 1% EDDHA (30, 40 & 50 DAS), T_{11}: RDF + FS of 1% TNAU Fe citrate (30, 40 & 50 DAS). These treatments were imposed in Randomized Block Design (RBD) with three replications. The Groundnut variety VRI 8, released by Tamil Nadu Agricultural University (TNAU) was taken as test variety for the present study. The VRI 8 groundnut seeds were treated with *Rhizobium* and PSB then sown at a depth of 5 cm using recommended seed rate and fertilizers were applied @ 25 kg N and 50 kg P_2O_5 ha^{-1}. N and K was given in three splits *viz.*, 50% of N and K as basal + 25% N and K at 20 DAS + 25 percent N and K at 45 DAS, whereas P was completely given as basal according to the treatment schedule. Gypsum was applied @ 400 kg ha^{-1} in two splits before sowing and on 45th day after flowering. Foliar application of 1% $FeSO_4$, Fe-EDDHA and TNAU Fe citrate were applied to the selected plots as per the treatment schedule at 30, 40 and 50 DAS of crop growth. The plant height, yield attributes *viz.*, number of pods, 100 kernel weight, DMP as well as pod and haulm yield of groundnut were recorded.

Oil content in kernel was determined by Soxhlet apparatus using petroleum ether (60-80^{0}C) as an extractant (A.O.A.C., 1960) [1]. Protein percent in kernels was calculated by multiplying nitrogen concentration percentage in kernel by the factor of 6.25 (A.O.A.C., 1960) [1].

Table 1: Initial status of soil properties at the experimental site

Soil properties	Value
A. Mechanical Composition	
Clay (%)	41.10
Silt (%)	43.23
Sand (%)	13.10
Textural class	Silty clay
B. Physical properties	
Bulk density (Mg m^{-3})	1.41
Particle density (Mg m^{-3})	2.36
Total porosity (%)	41.1
C. Chemical properties	
Organic carbon (g kg^{-1})	3.6
Free $CaCO_3$ (%)	11.5
Available N (kg ha^{-1})	257.6
Available P_2O_5 (kg ha^{-1})	15.6
Available K_2O (kg ha^{-1})	336
Available Fe (ppm)	5.28
EC (dS m^{-1})	0.82
Soil pH	8.35

Results and Discussion

Effect of iron fertilization on plant height

It was observed that the plant height increased linearly with the advancement of crop growth due to treatments wherein the plant height ranged from 28.40 to 33.50, 42.53 to 48.90 and 42.97 to 52.60 cm at 45th, 75th DAS and at harvest stage respectively (Table 2). Application of RDF + Fe-EFYM @ 50 kg ha^{-1} +*Bacillus subtilis* @2 kg ha^{-1} (T_7) was found to register significantly higher plant height of 33.20, 48.90 and 52.60 cm ^{1} at 45th, 75th DAS and at harvest stages respectively as compared to the other treatments and control. On other hand, the lowest plant height of 28.40, 42.53 and 42.97 cm at 45th, 75th DAS and at harvest stages respectively were recorded in treatment with RDF alone (Table 2). The increase in plant height might be due to the addition of Fe enriched FYM along with *Bacillus subtilis* which resulted in improvement in vegetative structure for nutrient absorption and photosynthesis. Increase in plant height, number of leaves and number of branches may be due to the involvement of Fe in chlorophyll formation, which might have helped to favor cell division, meristematic activity in apical tissue, expansion of cell and formation of new cell wall (Singh *et al.*, 1989) [9]. Prakash Rao (1998) [6] observed plant height and photosynthetic rate with the increased level of Fe application. The results are in line with Damor *et al.*, 2019 [11] in groundnut and Gurjar (2012) [2] in mustard.

Table 2: Effect of different source and levels of iron on plant height of groundnut

Treatment	Plant height (cm)		
	45 DAS	75 DAS	HS
T1: RDF (25:50:75 NPK kg ha^{-1})	28.40	42.53	42.97
T2: RDF + $FeSO_4$ @ 50 kg ha^{-1}	31.00	46.20	47.30
T3: RDF + Fe-EFYM@37.5 kg ha^{-1}	31.87	46.90	48.33
T4: RDF + Fe-EFYM@50 kg ha^{-1}	32.00	47.40	48.80
T5: RDF + $FeSO_4$ @ 50 kg ha^{-1} + *Bacillus subtilis* @ 2 kg ha^{-1}	32.30	48.10	49.00
T6: RDF + Fe-EFYM@ 37.5 kg ha^{-1} + *Bacillus subtilis* @ 2 kg ha^{-1}	32.80	48.27	50.20
T7: RDF + Fe-EFYM @ 50 kg ha^{-1} + *Bacillus subtilis* @ 2 kg ha^{-1}	33.50	48.90	52.60
T8: RDF + Fe-EDDHA @ 5 kg ha^{-1} + FS of 1% $FeSO_4$ (30, 40 & 50 DAS)	30.70	46.10	47.00
T9: RDF + FS of 1% $FeSO_4$ (30, 40 & 50 DAS)	30.20	43.53	43.97
T10: RDF + FS of 1% EDDHA (30, 40 & 50 DAS)	30.53	43.90	44.60
T11: RDF + FS of 1% TNAU Fe citrate (30, 40 & 50 DAS)	29.97	43.20	43.80
SEd ±	0.74	0.83	1.05
CD (P=0.05)	1.55	1.73	2.20

Effect of iron fertilization on protein content and oil yield

The results of the crude protein presented in Table 3 showed that the application of Fe-EFYM along with *Bacillus subtilis* significantly influenced the crude protein content of the groundnut kernel. The highest crude protein content of 14.56 percent was recorded in the treatment plot with Fe-EFYM @ 50 kg ha^{-1} along with *Bacillus subtilis* @ 2 kg ha^{-1} and RDF (T_7). The oil yield of groundnut ranged from 362 to 966 kg ha^{-1}. The result of statistical analysis showed that soil application of 50 kg Fe-EFYM along with *Bacillus subtilis* @ 2 kg ha^{-1} and RDF (T_7) recorded significantly the highest oil yield of 966 kg ha^{-1}, which was statistically superior to other treatments which ensured better biosynthesis of oil in groundnut. It is also supported by Yadav (2009) who observed that increasing $FeSO_4$ level up to 50 kg ha^{-1} increased protein content in kernels of groundnut. The increased in oil and protein content have also been reported by Patel *et al.*, (2010) in grain, Amaranth and Gurjar (2012) [2] in mustard crop respectively. Likewise similar results were observed by Damor *et al.*, 2019 [11] and Poonai *et al.*, 2018 in groundnut.

Table 3: Effect of different source and levels of iron on protein content and oil yield of groundnut seed

Treatment	Oil yield (kg ha^{-1})	Protein content in kernel (%)
T1: RDF (25:50:75 NPK kg ha^{-1})	362	12.56
T2: RDF + $FeSO_4$ @ 50 kg ha^{-1}	703	14.13
T3: RDF + Fe-EFYM@37.5 kg ha^{-1}	760	14.25
T4: RDF + Fe-EFYM@50 kg ha^{-1}	811	14.44
T5: RDF + $FeSO_4$ @ 50 kg ha^{-1} + *Bacillus subtilis* @ 2 kg ha^{-1}	838	14.19
T6: RDF + Fe-EFYM@ 37.5 kg ha^{-1} + *Bacillus subtilis* @ 2 kg ha^{-1}	908	14.31
T7: RDF + Fe-EFYM @ 50 kg ha^{-1} + *Bacillus subtilis* @ 2 kg ha^{-1}	966	14.56
T8: RDF + Fe-EDDHA @ 5 kg ha^{-1} + FS of 1% $FeSO_4$ (30, 40 & 50 DAS)	620	13.94
T9: RDF + FS of 1% $FeSO_4$ (30, 40 & 50 DAS)	530	13.69
T10: RDF + FS of 1% EDDHA (30, 40 & 50 DAS)	551	13.81
T11: RDF + FS of 1% TNAU Fe citrate (30, 40 & 50 DAS)	507	13.63
SEd	17.33	0.31
CD(P=0.05)	36.15	0.65

Effect of iron fertilization on yield attributing characters

As detailed in Table 4, the soil application of Fe-EFYM @ 50 kg ha^{-1} with *Bacillus subtilis* @ 2 kg ha^{-1} and RDF recorded the highest number of pods per plant of 38.67 as compared to other treatments. It was on-par with the treatment receiving Fe-EFYM @ 37.5 kg ha^{-1} + *Bacillus subtilis* @ 2 kg ha^{-1} + RDF (T_6) with 37.33 number of pods $plant^{-1}$. The treatment applied with recommended dose of fertilizers (T_1) registered lowest number of pods per plant (20.33).

The hundred kernel weight registered significant response to the application of iron as shown in the Table 4. Soil application of Fe-EFYM @ 50 kg ha^{-1} with *Bacillus subtilis* @ 2 kg ha^{-1} + RDF registered the highest 100 kernel weight of 48.69 g (T_7). The lowest value was recorded in the control which received RDF alone (T_1) of 36.17 g. The increase in the pod weight and 100 kernel weight could be due to continuous supply of organically cheated Fe to the crop. Iron are part of the photosynthesis, assimilation and translocation of photosynthesis from source (leaves) to sink (pod). The results are in accordance with those reported by Gurjar (2012) [2] in mustard. It is also corroborated by Kumar *et al.* (2009) [3] who 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.

Effect of iron fertilization on pod yield and haulm yield

Groundnut pod yield was statistically analysed, and the results showed that treatment (T_7) with 25:50:75 NPK kg ha^{-1} + 50 kg Fe enriched FYM + *Bacillus subtilis* @ 2 kg ha^{-1} had a considerably greater pod production of 2090 kg ha^{-1} followed by treatment (T_6) 25:50:75 NPK kg ha^{-1} + 37.5 kg Fe enriched FYM + *Bacillus subtilis* @ 2 kg ha^{-1} (1978 kg ha^{-1}). Treatment T_5 (RDF + Soil application of 50 kg $FeSO_4$ kg ha^{-1} + Bacillus subtilis @ 2 kg ha^{-1}) produced a pod yield of 1841 kg ha^{-1}, statistically comparable to treatment T4 (RDF + 50 kg Fe enhanced FYM). The control (T_1) recorded the lowest pod production of 957 kg ha^{-1} while receiving only RDF (Table 4). A similar trend was also observed in haulm yield. Application of 50 kg Fe enriched FYM + *Bacillus subtilis* @ 2 kg ha^{-1} + RDF recorded highest haulm yield of 2891 kg ha^{-1} and lowest haulm yield recorded in T_1 (1947 kg ha^{-1}) (Table 4). Remarkable response of Fe-enriched FYM and *Bacillus subtilis* on pod and haulm yield in the current study can be related to the enrichment technique's ability to mobilize native nutrients and improve their availability. The addition of Fe in a naturally chelated form, which is anticipated to become slowly available to growing crops over a longer period of time, thus contributing to balanced Fe nutrition while complementing other necessary elements and keeping them available to the crop for a longer period of time, which promotes greater crop growth. Kumawat *et al.* (2006) [4] observed that the soil application of Fe at 25 kg $FeSO_4$ ha^{-1} recorded significantly higher seed and straw yield of summer mung bean as compared to control. Sahu *et al.* (2008) [8] 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 (1423 kg ha^{-1}) as compared to control in chickpea. Similar results was reported by Kumar *et al.* (2009) [3] who observed that the application of 10 kg Fe ha^{-1} enhanced the grain yield of chickpea by 17.3% over control. Similar trend in straw yield response was also recorded. Sharma *et al.* (2010) reported that the application of chelated Fe (1 or 2 kg ha^{-1}), significantly increased all the yield contributing characteristics *viz.*, number of pods per plant, number of seeds per pod and 100 seeds weight in pigeon pea crop.

Table 4: Effect of different source and levels of iron on yield attributes and yield of groundnut

Treatments	No of Pod plant^{-1}	100 grain weight (g)	Pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
T1: RDF (25:50:75 NPK kg ha^{-1})	20.33	36.17	957	1947
T2: RDF + $FeSO_4$ @ 50 kg ha^{-1}	32.00	42.15	1632	2425
T3: RDF + Fe-EFYM@37.5 kg ha^{-1}	32.00	43.66	1738	2554
T4: RDF + Fe-EFYM@50 kg ha^{-1}	34.00	44.68	1842	2704
T5: RDF + $FeSO_4$ @ 50 kg ha^{-1} + *Bacillus subtilis* @ 2 kg ha^{-1}	36.00	45.20	1883	2741
T6: RDF + Fe-EFYM@ 37.5 kg ha^{-1} + *Bacillus subtilis* @ 2 kg ha^{-1}	37.33	46.52	1978	2786
T7: RDF + Fe-EFYM @ 50 kg ha^{-1} + *Bacillus subtilis* @ 2 kg ha^{-1}	38.67	48.69	2090	2891
T8: RDF + Fe-EDDHA @ 5 kg ha^{-1} + FS of 1% $FeSO_4$ (30, 40 & 50 DAS)	30.00	41.22	1449	2308
T9: RDF + FS of 1% $FeSO_4$ (30, 40 & 50 DAS)	24.00	39.77	1278	2240
T10: RDF + FS of 1% EDDHA (30, 40 & 50 DAS)	26.00	40.50	1312	2276
T11: RDF + FS of 1% TNAU Fe citrate (30, 40 & 50 DAS)	22.00	39.41	1215	2192
SEd ±	0.79	0.785	30.66	57.73
CD(P=0.05)	1.66	1.639	63.95	120.66

Conclusion

Based on the results of present study, it can be concluded that Fe-EFYM along with *Bacillus subtilis* was beneficial in increasing the yield of groundnut crop. Higher pod and haulm yield can be obtained by soil application of 50 kg Fe-EFYM along with *Bacillus subtilis* @ 2 kg ha^{-1} and RDF (25:50:75 NPK kg ha^{-1}). The application of Fe-EFYM also enhances oil yield and protein content in kernel of groundnut.

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