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RESEARCH ARTICLE

Iron release characteristics in groundnut growing red and black calcareous soils of Cuddalore district

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Abstract

The current study was assessed the nutrient release pattern of iron using different sources of iron fertilizer at various levels in groundnut-growing red and black calcareous soils of the Cuddalore district at regular sampling intervals. The study design was completely randomized block design with different levels of iron sulphate ($FeSO_4$) at 25 and 50 kg ha^{-1}, iron-enriched farmyard manure (Fe-EFYM) at 37.5 and 50 kg ha^{-1} and iron-ethylene diamine dihydroxy phenylacetic acid (Fe-EDDHA) at 1 and 5 kg ha^{-1} three replicates at different sampling intervals of incubation. The release pattern of iron was analyzed. The study revealed that the releasing rate of iron increased with the advancement of the incubation period up to 42 days and thereafter declined in both type of calcareous soil. The maximum release of iron was found with the application of 50 kg $FeSO_4$ ha^{-1} as Fe- EFYM, which recorded mean values of 26.92 and 26.13 mg kg^{-1} on 42nd day in red and black calcareous soils, respectively. Application of Fe-EDDHA at 5 kg ha^{-1} recorded a gradual increase in DTPA iron availability from 7th day (17.35 mg kg^{-1} and 12.03 mg kg^{-1} in red and black calcareous soil, respectively) to 42nd day (21.49 mg kg^{-1} and 18.87 mg kg^{-1} in red and black calcareous soil respectively). Then it showed a steady decline in both calcareous soils. The results of the current study showed that the efficient usage of iron in both calcareous soils was greatly increased by the combined application of organic and inorganic fertilizers.

Keywords

calcareous soil; $FeSO_4$; Fe-EFYM; Fe- EDDHA; iron; nutrient release

Introduction

Iron (Fe) is the fourth most common element in the soil. Among micronutrients, Fe was the first micronutrient identified as essential for plant growth. In the metabolic processes of plants, Fe is necessary for several respiratory enzymes and metabolic activities related to photosynthesis. Legumes extensively use iron for nodule formation to fix atmospheric nitrogen. The protein content of peanut kernels was also increased by Fe fertilization. Green plant tissue contains 50-100 mg of iron per kilogram of dry weight (1). Therefore, Fe is one of the most prominent micronutrients in plants (2).

Mineral Fe is involved in numerous metabolic activities such as photosynthesis and cell respiration. Regardless of the Fe nutritional status, over 80% of the Fe in green leaves is concentrated in the chloroplasts. Iron has the potential to form chelates and can undergo reversible oxidation-reduction reactions, being the two important features underlying its range of physiological effects (1, 3). Fe is not incorporated into the actual chlorophyll structure, although it plays a catalytic role in numerous reactions that lead to chlorophyll biosynthesis. Fe regulates the common precursors of heme and chlorophyll synthesis (4).

Iron can be complexed by organic compounds, which improves its solubility and mobility (5). Compounds that are particularly effective in chelating Fe are found in organic amendments. Humic acids, amino acids, phenolics, hydroxamates and catechol siderophores are the most common chelators of Fe found in organic sources (6). In addition to providing chelators that increase Fe solubility, organic sources also encourage microbial activity, providing effective siderophores (7, 8). Iron sulphate ($FeSO_4$) is a widely used fertilizer because of its fast solubility and low cost; however, nutrient fixation in the soil is a primary issue. In such situations, other methods, such as the use of synthetic chelates, can be used to increase the lack of micronutrient utilization. To improve iron availability in the soil and correct iron chlorosis in plants, organic manures, Fe chelates, and inorganic fertilizers such as $FeSO_4$ were applied to iron-deficient soil through soil application and foliar spraying, respectively. In calcareous soil, the application of Fe chelates like Fe-EDDHA, Fe-EDTA and Fe-DTPA was highly effective for sustaining soil solution Fe. With the soil having a high pH and calcareousness, the recovery ability of Fe from FeSO4 was negligible (9-11). Using organic manures that serve as natural chelates for enrichment, rather than expensive synthetic chelates such as iron -ethylene diamine tetra acetic acid (Fe-EDTA) and iron-ethylene diamine dihydroxy phenyl acetic acid (Fe-EDDHA) Fe-EDDHA, appears to be a cost-effective strategy. There are numerous iron fertilizers for preventing iron chlorosis, but their high cost typically prevents the widespread use of iron sources in agriculture (12). Thus, higher nutrient release is possible by combining manure and inorganic fertilizers.

Few investigations on the various sources and levels of iron release have been published. Consequently, a laboratory incubation experiment was conducted to study the pattern of Fe release after the addition of different sources and levels of iron fertilizer.

Materials and Methods

Incubation studies were carried out in the Department of Soils and Environment, Agricultural and College and Research Institute, Madurai, India, during 2021-2022 to study the release pattern of Fe fractions from different fertilizer sources *viz.,* $FeSO_4$, Fe-EFYM and Fe-EDDHA in red and black calcareous soils. The black calcareous soil samples from Magulam village in Mangalur Block and red calcareous soil samples from Arasakuzhi village in Vridhachalam Block in the Cuddalore district were collected and assessed for the availability of iron in the soil. Soil samples from the above-mentioned areas were collected, processed and utilized for incubation studies. The initial soil analytical report for black and red calcareous soil is shown in Table 1. In black calcareous soil, the soil was silty clay with an alkali pH and the electrical conductivity of the soil was less than 4 dS m^{-1} which indicates that the soil was free from salinity. The organic carbon status was found to be low with a cation exchange capacity of 34.5 c mol (p+) kg^{-1}. The fertility status was found to be low in available nitrogen, medium in available phosphorus and high in available potassium. The available iron status of the soil was below its critical level.

Table1. Initial soil properties of the experimental soil

Parameters	Black calcareous soil	Red calcareous soil
Textural class	Silty Clay	Sandy Clay Loam
Soil reaction (1: 2.5 Soil: water)	8.35	8.67
Electrical conductivity (dS m^{-1})	0.82	0.49
Organic carbon (g kg^{-1})	3.60	3.96
Free calcium carbonate (%)	11.5	11.9
Available nitrogen (kg ha^{-1})	257.6	242
Available phosphorus (kg ha^{-1})	15.6	10.54
Available potassium (kg ha^{-1})	336	276
Available iron (ppm)	5.28	5.02

The farmyard manure was physically mixed @1:10 with $FeSO_4$ and manure for enrichment in a plastic bag. The component was properly combined and moistened to the required amount using deionized water to ensure moist friable manure. The FYM were mixed with $FeSO_4.7H_2O$ and the moisture level was maintained at about 60% during the enrichment process (13). The polyethylene bags were clipped with rubber bands and placed on a laboratory worktable at room temperature for a month. To speed up decomposition, the mixture was rotated once a week, kept damp and given two hours to release CO_2 and relieve any CO_2 stress on microbial activity (14). The polyethylene bags were additionally weighed every three days, the weight recorded and the difference between the two weights was made up by adding deionized water to maintain a constant moisture level. The composition of FYM and Fe-EFYM is presented in Table 2. A 500 ml container containing 200 g of soil samples was used to study the laboratory incubation research for the soil's Fe release pattern. Under laboratory conditions, soil samples were periodically maintained at field capacity (21% gravimetric).

Soil samples were drawn from each container at seven days intervals (7, 14, 21, 28, 35, 42, 49, 56 and 63 days of incubation) and analyzed for soil DTPA-Fe using standard procedures (15). The incubation study was conducted using a completely randomized design that was replicated thrice with different treatment combinations, *viz.,* T1 - Control, T_2 - 25 kg ha^{-1} $FeSO_4$, T_3- 50 kg ha^{-1} $FeSO_4$, T_4 - $FeSO_4$as Fe-enriched farmyard

Table 2. Composition of FYM and Fe-EFYM

Nutrients	Content (%)	
	FYM	Fe-EFYM
Nitrogen	0.76	1.24
Phosphorus	0.69	0.72
Potassium	0.67	0.73
Zinc	0.0005	0.0059
Copper	0.0006	0.00062
Manganese	0.009	0.018
Iron	0.09	0.6

manure @ 37.5 kg ha^{-1}, T_5 - $FeSO_4$ as Fe-enriched farmyard manure @ 50 kg ha^{-1}, T_6 - 1 kg ha^{-1} Fe- EDDHA, T_7- 5 kg ha^{-1} Fe-EDDHA.

The data obtained from the incubation study were subjected to statistical analysis using AGRESS software version 7.01. The level of significance was set at P < 0.05. Critical difference (CD) values were calculated for the P < 0.05 whenever the "F" test was found significant (16).

Results

To study the availability of Fe in red and black calcareous soils, an incubation experiment was conducted with different sources of Fe ($FeSO_4$, Fe-EFYM and Fe-EDDHA) and different levels of Fe on the availability of Fe at different incubation time intervals. The results revealed that different sources and levels of Fe had a significant effect on the release pattern of nutrients at different incubation intervals.

The treatments comprised of control (T_1), 25 kg $FeSO_4$ ha^{-1} (T_2), 50 kg $FeSO_4$ ha^{-1} (T_3), 37.5 kg $FeSO_4$ ha^{-1} as Fe-EFYM (T_4), 50 kg $FeSO_4$ ha^{-1} as Fe-EFYM (T_5), 1kg ha^{-1} Fe-EDDHA (T_6) and 5 kg ha^{-1} Fe-EDDHA (T_7). The samples were incubated for 65 days at the field capacity level. Once a week, soil samples were collected and over time, the available iron was determined.

The findings showed that increasing levels of iron greatly increased the release of iron in red and black calcareous soils over time (from the 7th days to the 42nd days of incubation). Using different sources of iron, iron availability increased with time and levels of iron. In both calcareous soils, the amount of available iron increased with the advancement of the incubation period up to the 42nd day and decreased from the 49th day onwards.

Increasing levels of Fe addition through different sources increased Fe availability and the highest available Fe was recorded with the addition of 50 kg $FeSO_4$ ha^{-1} as Fe-EFYM (T_5), followed by the addition of 37.5 kg $FeSO_4$ ha^{-1} as Fe- EFYM (T_4). The rate of iron release was higher in treatment T_5 (50 kg $FeSO_4$ ha^{-1} as Fe-EFYM) until 42nd day and thereafter declined from the 49th days. The maximum release of iron was found to be with the application of 50 kg $FeSO_4$ ha^{-1} as Fe-EFYM, with recorded values of 26.92 and 26.13 mg kg^{-1} in red and black calcareous soils, respectively.

The maximum mean of iron release was found in T_5 (50 kg $FeSO_4$ ha^{-1} as Fe- EFYM) and the mean values ranged from 24.59 to 23.88 mg kg^{-1} in red and black calcareous soils. Next to this treatment, T_4 (37.5 kg $FeSO_4$ ha^{-1} as Fe-EFYM) recorded highest available iron concentration of 22.11 and 20.70 mg kg^{-1} in red and black calcareous soil respectively followed by T_3, T_7, T_2 and T_6. The addition of FYM had a significant influence on the amount of iron released. While $FeSO_4$applied at 25 kg ha^{-1} (T_2) and 50 kg ha^{-1} (T_3) showed a mean value of 17.14 and 20.98 mg kg^{-1}of available iron content in red calcareous soil, respectively. In black calcareous soil registered a mean value of 12.66 and 17.09 mg kg^{-1} of available Fe content in black calcareous soil supplied 25 kg $FeSO_4$ ha^{-1} (T_2) and 50 kg $FeSO_4$ ha^{-1} (T_3) respectively.

Among the treatment T_6 and T_7, addition of Fe-EDDHA at the rate of 5 kg ha^{-1} (T_7) registered the maximum mean available iron content of 19.07 and 15.57 mg kg^{-1} in red and black calcareous soils respectively. Followed by this, the treatment applied with 1 kg of Fe- EDDHA (T_6) recorded 15.97 and 10.57 mg kg^{-1} in red and black calcareous soil.

In control, the lowest availability of Fe content was observed, which recorded the values of 5.20 and 4.66 mg kg^{-1} in red and black calcareous soils respectively. A gradual decrease was observed during the incubation period.

Discussion

The experiment on the release pattern of Fe nutrients from the applied sources provides a thorough understanding of the applicability and performance of additional fertilizers in crop production. Understanding how micronutrients are converted in the soil through the application of enhanced manure (FYM) is crucial because it affects the availability of these essential and significant plant nutrients. Most of the Fe required by the plants must be supplied by the soil fertilizer reaction products, not the applied water-soluble micronutrient fertilizer. This assumes that the significance of Fe transition in soil is true. A study was conducted on the Fe-release patterns of $FeSO_4$, Fe-EFYM and Fe -EDDHA. Modified soils were evaluated over time to determine whether they could support agricultural production.

In red and black calcareous soil, Fe release was at its maximum with increasing time intervals up to 42 days before declining. With the application of 50 kg $FeSO_4$ ha^{-1} as Fe-EFYM, the maximum release of Fe in red and black calcareous soils was 26.92 and 26.13 mg kg^{-1} at 42nd days, respectively (Fig. 1 & 2). The availability of Fe increased with increasing levels of Fe through FYM and the highest DTPA Fe status was recorded with the addition of 50 kg Fe- EFYM. The addition of iron-containing fertilizers and the mineralization and release of Fe from organic matter during decomposition have been shown to significantly increase the availability of Fe in the soil. A rise in soil microbial activity brought on by additional organic material addition may have contributed to the release of Fe from complex organic compounds (17-19). The formation of organometallic complexes with Fe may have decreased its fixation by clay minerals or its precipitation as $FePO_4$, increasing the availability of Fe with the addition of organic matter (20).

DTPA-Fe had a more noticeable impact than other critical elements, which may be associated with the residual Fe that was left behind in the soil after the crop was harvested in proportion to the depletion. Several researchers have noted

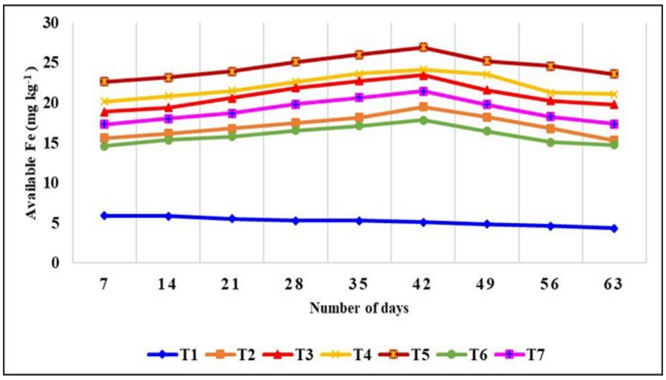

Fig. 1. Effect of levels and source of iron on releasing pattern of iron in red calcareous soil

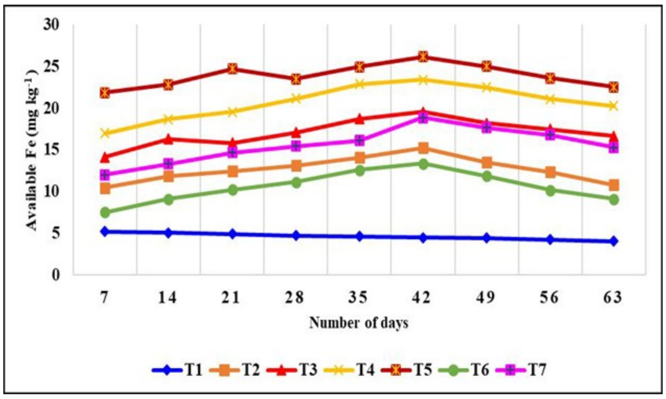

Fig. 2. Effect of levels and source of iron on releasing pattern of iron in black calcareous soil

that the addition of iron to soil results in higher iron concentrations (21-23).

Because FYM is responsible for generating a variety of organic acids that may have acted as chelating agents and prevented the release of iron from accumulating with calcium in the soil, the increase in iron due to FYM may be attributed to their chelating effect. Furthermore, it is consistent with the findings of Katyal *et al*., (24) who found that the organic acids or chemicals produced during the breakdown of organic matter react with iron to form soluble organo-iron complexes that prevent iron from being fixed by soil components. The increased iron availability might be due to the role of humic substances in the manure, which increased iron availability by preventing their transformation into insoluble hydroxides, chelation action, and release in labile forms (25). A similar finding was also reported in soil by Latha *et al.,* (26) and who found a significant influence of Fe-fortified vermicompost on iron availability due to the complexation or chelation action, contribution from manures and prevention of iron fixation (27, 28).

Conclusion

From this study, it was concluded that with the combined application of organic and inorganic fertilizers, an increase in iron availability was observed in black and red calcareous soil. On the 42nd day, the DTPA-Fe availability was higher when the Fe was applied with an organic source, that is, the application of 50 kg of $FeSO_4$ ha^{-1} as Fe-EFYM recorded maximum availability both in red and black calcareous soil.

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Authors' contributions

GP and RS conceived of the project and designed the experiments. GP and RS analysed the data. RS, MPS and PR assisted the data, prepared the figures and tables and prepared the manuscript. KB, GA and MK validated the statistical data All authors approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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