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# Iron fertilization to alleviate iron deficiency in irrigated maize hybrid in non-calcareous soil

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**Abstract**
Field experiments were conducted to study the effect of iron fertilization to alleviate iron deficiency in irrigated maize hybrid in non calcareous soil. The design of the experiment was Randomized Block Design (RBD). The experimental soil is sandy loam at MRS, Vagarai. The effect of Tamil Nadu Agricultural University micro nutrient (MN) mixture and $FeSO_4$ were studied by applying it as a direct chemical fertilizer and as enriched form with and without $FeSO_4$ foliar spray. Among the different treatments, The highest grain yield was recorded in 100% RDF+ Basal application of TNAU MN mixture @ 30 kg $ha^{-1}$ as EFYM + Foliar spray of 1% $FeSO_4$ at 30 DAS followed by 100% RDF+ Basal application of TNAU MN mixture @ 30 kg $ha^{-1}$ as EFYM and the lowest being in 100% RDF. The soil iron content showed significant difference due to different treatments at 45 DAS and at harvest. Application of $FeSO_4$ enriched application showed higher Fe content in soil when compared to the application of TNAU MN mixture either straight or enriched application in non calcareous soils. Application of TNAU MN mixture either straight or enriched was found to be good in enhancing the Fe uptake of the crop in grain and stalk at harvest due to the higher DMP and yield parameters.

**Keywords:** iron fertilization – non calcareous soil - Mitigation measures -TNAU MN mixture- EFYM

## Introduction
Iron deficiency is a limiting factor of plant growth. Iron is present at high quantities in soils, but its availability to plants is usually very low, and therefore iron deficiency is a common problem. Plants can uptake iron in its oxidized forms such as $Fe^{2+}$ (ferrous form) and $Fe^{3+}$ (ferric form), but although most of the iron on the earth crust is in the form of $Fe^{3+}$, the $Fe^{2+}$ form is physiologically more significant for plants. This form is relatively soluble, but is readily oxidized to $Fe^{3+}$, which then precipitates. $Fe^{3+}$ is insoluble in neutral and high pH, making iron unavailable to plants in alkaline soils. Furthermore, in soil, iron readily combines with phosphates, carbonates, calcium, magnesium and hydroxide ions. Maize is one of the most important cereals broadly adapted worldwide (Christian *et al.*, 2012) [5]. It is an important field crop in terms of area coverage, production and utilization for food and feed purposes. Enhancement of maize production and productivity can be achieved through proper supplementation of plant nutrition. Intensive cultivation of high yielding maize varieties requires application of plant nutrients in large quantities (Mosisa *et al.*, 2007) [12]. Micronutrient deficiency limits plant growth and affects crop yield, especially in calcareous soil (Elham *et al.*, 2014) [7]. Fe is needed to produce chlorophyll hence its deficiency causes chlorosis turning yellow or brown in the margins between the veins which may remain green, while young leaves may appear to be bleached (Broadley *et al*. 2007; Christin *et al*. 2009) [4, 6]. Fe is also essential for plant growth, photosynthesis, enzymatic processes such as those related to oxygen and electron transport, nitrogen fixation, DNA and chlorophyll biosynthesis (Briat 2007; Jeong & Guerinot 2009) [3, 9]. Beside transgenic approaches, enrichment (biofortification) of food crops with Fe through agricultural approaches is a widely applied strategy (Pfeiffer & McClafferty 2007; Borg *et al*. 2009) [15, 2]. Control of Fe chlorosis is not easy and can be expensive too. Most of the studies dealing with soil and foliar application of Fe fertilizers focused on correction of Fe deficiency chlorosis and improving yield (Rombola *et al*. 2000) [16]. One way of replenishing nutrients in the arable lands is to recycle nutrients through application of organic material such as litter, crop residues, and manures (Lekasi *et al.*, 2000; Agele *et al.*, 2005) [11, 1]. Organic manures, especially farmyard manure, have a significant role for maintaining and improving the chemical, physical and biological properties of soils. Organic materials play a critical role in sustainability in the arid and semi-arid regions

(Heluf *et al.*, 1999) [8]. Despite this importance, there is little predictive understanding for the management of organic inputs in arid and semi-arid agro ecosystems. It is now widely recognized that soil organic matter plays an important role in soil chemical (pH, base saturation, salinity and CEC changes) physical (bulk density, stabilization of soil structure and aggregate formation) properties and biological properties. Organic manures, especially farmyard manure, have a significant role for maintaining and improving the chemical, physical and biological properties of soils. Zelalem Bekeko (2014) [18] concluded in his studies that enriched FYM can be used for hybrid maize production at western Hararghe in order to get maximum grain yield of BH-140 and maximum farm return. Besides Tamil Nadu agricultural University has developed micronutrient mixture to alleviate micro nutrient deficiency in number of field crops. Hence the present study was conducted to study the effect of iron fertilization on growth, yield and yield parameters of maize and the iron availability in soil and its uptake in maize hybrid in a non calcareous soil.

## Materials and Methods

Field experiments were conducted to study the effect of iron fertilization to alleviate iron deficiency in calcareous soil at farmers holding at Vagarai village, Dindigul District Tamil Nadu for two consequent years. First year sowing was taken up with maize hybrid COHM5 with a spacing of 60 x 25 cm. The experimental soil type is sandy loam with the initial soil pH 7.41 and EC of 0.25 $dSm^{-1}$. Soil had low N (150.6 kg $ha^{-1}$), medium Phosphorus (19.2 kg $ha^{-1}$), high potassium (589.3 kg $ha^{-1}$) DTPA- Fe content of 2.0 mg $kg^{-1}$. Second year sowing was taken up on 13.12.12 with the same hybrid. The initial soil pH was 7.41 and EC of 0.20 $dSm^{-1}$ respectively. Soil had low nitrogen (196 kg $ha^{-1}$), medium phosphorus (18.2 kg $ha^{-1}$), high potassium (693 kg $ha^{-1}$), DTPA-Fe content of 2.4 mg $kg^{-1}$.

**The treatment details are as follows**

$T_1$ - 100 % RDF
$T_2$ - $T_1$ + Basal application of $FeSO_4$ 50.0 kg $ha^{-1}$
$T_3$ - $T_1$ + Basal application of $FeSO_4$ 37.5 kg $ha^{-1}$ as EFYM
$T_4$ - $T_1$ + Foliar spray of 1% $FeSO_4$ at 30 DAS
$T_5$ - $T_2$ + Foliar spray of 1% $FeSO_4$ at 30 DAS
$T_6$ - $T_3$ + Foliar spray of 1% $FeSO_4$ at 30 DAS
$T_7$ - $T_1$ + Basal application of TNAU MN mixture @ 30 kg $ha^{-1}$
$T_8$ - $T_1$ + Basal application of TNAU MN mixture @ 30 kg $ha^{-1}$ as EFYM
$T_9$ - $T_7$ + Foliar spray of 1% $FeSO_4$ at 30 DAS
$T_{10}$ - $T_8$ + Foliar spray of 1% $FeSO_4$ at 30 DAS

The design of the experiment was Randomized Block Design (RBD) with three replications. Biometric observations, yield parameters and yield were recorded. DTPA extractable soil Fe and Fe content in the plant were analysed on 45 DAS and at harvest using Atomic Absorption Spectrophotometer. The Fe uptake was computed by multiplying the Fe content with Dry matter production.

## Results and Discussion

During first year the plant height recorded at flowering failed to show significant difference, whereas, the plant height at harvest showed significant variation due to different treatments. The plant height was the highest in T10, which received the application of 100 % RDF along with TNAU MN mixture@ 30 kg $ha^{-1}$ as EFYM and foliar spray of 1% FeSO4 at 30 DAS and the lowest plant height was recorded in T1 (100 % RDF) (Table 1). During second year the different treatments registered significant difference on the plant height at 45 DAS and at harvest. The plant height was the highest in the treatment T10 and the lowest plant height was recorded in T1. The highest yield parameters *viz*., cob length, girth and weight were observed in T10 (100% RDF+ Basal application of TNAU MN mixture @ 30 kg $ha^{-1}$ as EFYM + Foliar spray of 1% $FeSO_4$ at 30 DAS).

**Table 1:** The effect of iron fertilization on growth, yield and yield parameters of hybrid maize during first year

| Treatments | Plant height (cm) | | Cob length (cm) | Cob girth (cm) | Cob weight (g) | Grain Yield (kg $ha^{-1}$) | Stalk Yield (kg $ha^{-1}$) |
|---|---|---|---|---|---|---|---|
| | Flowering | Harvest | | | | | |
| $T_1$ | 148.6 | 170.4 | 15.3 | 10.2 | 145.2 | 4346 | 6845 |
| $T_2$ | 160.4 | 198.2 | 16.7 | 10.9 | 164.6 | 4654 | 7184 |
| $T_3$ | 162.7 | 212.3 | 17.1 | 11.3 | 172.5 | 4765 | 7399 |
| $T_4$ | 152.4 | 190.4 | 16.4 | 10.6 | 160.0 | 4584 | 7023 |
| $T_5$ | 172.0 | 225.2 | 17.5 | 12.2 | 170.6 | 5035 | 7545 |
| $T_6$ | 175.3 | 225.5 | 17.9 | 12.7 | 173.2 | 5192 | 7708 |
| $T_7$ | 162.0 | 217.8 | 17.4 | 11.0 | 169.6 | 4986 | 7453 |
| $T_8$ | 163.1 | 229.0 | 18.0 | 12.6 | 177.5 | 5286 | 8185 |
| $T_9$ | 172.8 | 227.6 | 17.8 | 12.4 | 175.9 | 4965 | 7854 |
| $T_{10}$ | 178.6 | 232.5 | 18.4 | 12.8 | 180.6 | 5423 | 8252 |
| SE-d | 10.3 | 13.3 | 0.79 | 0.64 | 6.28 | 315.9 | 405.9 |
| CD (p=0.05) | NS | 27.8 | 1.68 | 1.33 | 13.19 | 642.3 | 853.6 |

**Table 2:** The effect of iron fertilization on growth, yield and yield parameters of hybrid maize during second year

| Treatments | Plant height (cm) | | Cob length (cm) | Cob girth (cm) | Cob weight (g) | Grain Yield (kg $ha^{-1}$) | Stalk Yield (kg $ha^{-1}$) |
|---|---|---|---|---|---|---|---|
| | Flowering | Harvest | | | | | |
| $T_1$ | 155.4 | 175.3 | 16.0 | 13.8 | 163.2 | 5768 | 7545 |
| $T_2$ | 161.1 | 181.3 | 16.5 | 14.4 | 172.1 | 5989 | 8015 |
| $T_3$ | 170.6 | 190.2 | 17.2 | 14.7 | 180.2 | 6084 | 8587 |
| $T_4$ | 162.4 | 184.4 | 16.3 | 14.3 | 178.7 | 6132 | 8344 |
| $T_5$ | 170.1 | 199.5 | 17.1 | 15.1 | 180.9 | 6212 | 8763 |
| $T_6$ | 180.1 | 202.0 | 18.0 | 15.7 | 193.2 | 6632 | 8957 |
| $T_7$ | 166.8 | 210.6 | 17.5 | 15.5 | 177.4 | 6325 | 8453 |
| $T_8$ | 182.2 | 216.7 | 18.2 | 16.0 | 191.4 | 7125 | 9045 |
| $T_9$ | 176.3 | 213.5 | 18.0 | 15.7 | 185.3 | 6848 | 8879 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $T_{10}$ | 189.6 | 224.6 | 18.3 | 16.3 | 200.2 | 7342 | 9254 |
| SE-d | 8.59 | 11.07 | 0.66 | 0.75 | 9.22 | 240.5 | 263.6 |
| CD (p=0.05) | 18.06 | 23.25 | 1.39 | 1.58 | 19.38 | 505.3 | 553.8 |

The yield parameters were varied significantly due to various treatments and the highest cob length, girth and weight were observed in application of 100% RDF + basal application of TNAU MN mixture @ 30 kg $ha^{-1}$ as EFYM + foliar spray of 1% $FeSO_4$ at 30 DAS and it was statistically on par with T8, T9 and T6 during both the years. In the first year of study the highest grain yield of 7342 kg $ha^{-1}$ and stalk yield of 9254 kg $ha^{-1}$ were obtained with the application of 100% RDF + basal application of TNAU MN mixture @ 30 kg $ha^{-1}$ as EFYM + foliar spray of 1% $FeSO_4$ at 30 DAS and the lowest being in 100% RDF (Table 1). In second year study also the highest grain yield of 5423 kg $ha^{-1}$ was recorded in the treatment with the application of of 100 % RDF along with TNAU MN mixture@ 30 kg $ha^{-1}$ as EFYM and foliar spray of 1% FeSO4 at 30 DAS followed by T8 (5286 kg $ha^{-1}$) ; T9 (5192 kg $ha^{-1}$) and the lowest was observed in T1(100% RDF).The stalk yield also followed the same trend as that of grain yield (Table 2).

**Table 3:** The effect of iron fertilization on soil Fe and its uptake during first year

| Treatments | Soil DTPA- Fe (mg $kg^{-1}$) | | Fe uptake (g $ha^{-1}$) | |
|---|---|---|---|---|
| | 45 DAS | Harvest | 45 DAS | Harvest |
| $T_1$ | 2.3 | 2.5 | 77.7 | 117.3 |
| $T_2$ | 6.9 | 2.9 | 88.7 | 142.3 |
| $T_3$ | 7.2 | 2.6 | 90.4 | 131.3 |
| $T_4$ | 3.7 | 2.1 | 80.3 | 154.7 |
| $T_5$ | 7.8 | 3.0 | 113.5 | 183.7 |
| $T_6$ | 8.0 | 3.5 | 127.4 | 204.7 |
| $T_7$ | 8.2 | 3.8 | 126.9 | 203.5 |
| $T_8$ | 9.1 | 4.1 | 140.0 | 204.4 |
| $T_9$ | 7.9 | 3.9 | 143.6 | 246.2 |
| $T_{10}$ | 8.8 | 4.0 | 153.5 | 255.9 |
| SE-d. | 0.39 | 0.18 | 4.01 | 2.70 |
| CD (p=0.05) | 0.83 | 0.38 | 8.42 | 5.68 |

In both the years the soil iron content significantly varied due to different treatments at 45 DAS and at harvest. Application of $FeSO_4$ either as straight or enriched application showed numerically higher Fe content in soil. The combined addition of RDF, TNAU MN Mixture and Foliar spray of $FeSO_4$ might have increased the Fe content substantially. (Table 3 & 4) Moreover, it was stated that Fe contents increased in beans with the application of Fe (Karaman *et al*., 1997) [10]. It was observed that Fe contents increased by 21% as compared to control in wheat grains under the foliar application of iron (Pahlavan-Rad and Pessarakali, 2009) [13]. However the uptake of Fe was on the increasing side in treatments with the application of TNAU MN mixture either straight or enriched application due increased DMP at both stages

**Table 4:** The effect of iron fertilization on soil Fe and its uptake during second year

| Treatments | Soil DTPA- Fe (mg $kg^{-1}$) | | Fe uptake (g $ha^{-1}$) | |
|---|---|---|---|---|
| | 45 DAS | Harvest | 45 DAS | Harvest |
| $T_1$ | 2.81 | 2.23 | 75.7 | 166.3 |
| $T_2$ | 8.83 | 3.34 | 129.8 | 197.3 |
| $T_3$ | 9.14 | 3.82 | 151.4 | 217.9 |
| $T_4$ | 3.92 | 2.86 | 107.5 | 215.1 |
| $T_5$ | 8.96 | 3.84 | 158.6 | 247.1 |
| $T_6$ | 9.06 | 3.99 | 182.8 | 270.3 |
| $T_7$ | 7.83 | 3.21 | 141.0 | 256.3 |
| $T_8$ | 8.12 | 3.56 | 159.6 | 267.5 |
| $T_9$ | 8.06 | 3.33 | 155.1 | 272.0 |
| $T_{10}$ | 8.24 | 3.64 | 169.4 | 281.9 |
| SE-d | 0.73 | 0.21 | 5.2 | 19.1 |
| CD (p=0.05) | 1.52 | 0.44 | 10.6 | 40.0 |

The results stated that foliar application of $FeSO_4$ enhanced the Fe contents in mungbean grains, which significantly increased the seed quality. The same results also observed earlier by Patel *et al*. (1993) [14] with the application of iron sulfate on the groundnut plants.

## Conclusion

Application of 100% RDF along with basal application of TNAU MN mixture @ 30 kg $ha^{-1}$ as EFYM and foliar spray of 1% $FeSO_4$ at 30 DAS resulted in highest growth, yield and yield parameters in hybrid maize in calcareous soils. Application of MN mixture was found to be better in increasing the yield and yield parameters of maize when compared to the application of $FeSO_4$ alone. Application of $FeSO_4$ showed higher DTPA- Fe when compared to the application of TNAU MN mixture. Application of TNAU MN mixture was found to be good in enhancing the Fe uptake of the crop in grain and stalk due to the higher dry matter production and positive growth and yield parameters.

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