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C Bharathi
Assistant Professor (SS&AC) and Professor (Agronomy)
Department of Agronomy
Tamil Nadu Agricultural University, Coimbatore,
Tamil Nadu, India

Correspondence
C Bharathi
Assistant Professor (SS&AC) and Professor (Agronomy)
Department of Agronomy
Tamil Nadu Agricultural University, Coimbatore,
Tamil Nadu, India

Alleviating iron deficiency through iron fertilization in calcareous soil

Dr. C Bharathi

Abstract
Field experiments were conducted to study the effect of iron fertilization to alleviate iron deficiency in irrigated maize hybrid in calcareous soil in farmers holding at Vagarai village, Dindigul District, Tamil Nadu. The effect of Tamil Nadu Agricultural University Micro Nutrient (TNAU MN) mixture and ferrous sulphate ($FeSO_4$) were studied by applying it as a direct chemical fertilizer and as an enriched form with and without $FeSO_4$ foliar spray. The results revealed that, 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 stalk yield also followed the same trend as that of grain yield. 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. 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 due to the higher DMP and yield parameters.

Keywords: Iron fertilization - calcareous soil - TNAU MN mixture – EFYM- foliar spray

Introduction
The prime importance of trace elements in the nutrition of plants is indisputable. Iron (Fe) deficiency is a very common problem in calcareous soil and affects numerous agricultural crops throughout the world (Mengel *et al*., 1982; Moraghan & Mascagni 1991; Welch & Graham 2003) [9, 10, 16]. Micronutrient deficiency limits plant growth and affects crop yield, especially in calcareous soil (Elham *et al*., 2014) [5]. 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 and in calcareous soils. Furthermore, in these types of soil, iron readily combines with phosphates, carbonates, calcium, magnesium and hydroxide ions and makes it unavailable.

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 (Seeliger & Moss 1976; Haydon & Cobbett 2007; Broadley *et al*. 2007; Christin *et al*. 2009) [15, 6, 3, 4]. 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) [2, 7]. 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) [13, 1]. 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) [14]. Organic manures, especially farmyard manure, have a significant role in maintaining and improving the chemical, physical and biological properties of soils. Zelalem Bekeko (2014) [17] 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 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 the test crop was maize hybrid Pioneer- 30V96 with a spacing of 60 x 25 cm. The experimental soil type is sandy clay loam with the initial soil pH 8.3 and EC of 0.75 dSm^{-1}. Soil had low N (138.4 kg ha^{-1}), medium Phosphorus (8.2 kg ha^{-1}), high potassium (489.3 kg ha^{-1}) DTPA- Fe content of 2.8 mg kg^{-1} and free $CaCO_3$ content of 5.9%. Second year also same hybrid was used as a test crop with the initial soil characteristics of 8.1 and 0.34 dSm^{-1} for pH and EC respectively. The available nitrogen phosphorus and potassium was found to be low, medium and high respectively while DTPA- Fe content was 4.2 mg kg^{-1} and free $CaCO_3$ content of 5.5%.

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 Varian make Atomic Absorption Spectrophotometer. The Fe uptake was computed by multiplying the Fe content with Dry matter production.

Results and discussion

The results showed that the plant height recorded at both stages showed significant difference due to different treatments during first year. The plant height was the highest in the treatment T10 (T8 + Foliar spray of 1% $FeSO_4$ at 30 DAS) followed by T8 and the least plant height was recorded in T1. During second year the plant height recorded at 45 DAS showed significant difference. The plant height was the highest in the treatment T10 and the lowest plant height being in T1 whereas, the plant height failed to show significance at harvest.

Table 1: The effect of iron fertilization on yield and yield parameters

Treatments	Plant height		Cob length (cm)	Cob girth (cm)	Cob weight (g)	Grain Yield (kg ha^{-1})	Stalk Yield (kg ha^{-1})
	Flowering	Harvest					
First year							
T_1	125.5	164.5	15.5	10.1	135.2	3151	5231
T_2	141.6	171.2	16.3	10.9	152.5	3368	5694
T_3	147.2	178.6	16.8	11.5	155.3	3754	5772
T_4	140.6	169.5	16.0	11.3	150.4	3652	5545
T_5	152.2	183.0	17.0	11.8	158.0	4075	6570
T_6	157.5	196.3	17.2	12.0	163.4	4163	6805
T_7	143.5	175.0	16.9	11.8	155.5	4473	6400
T_8	155.3	205.5	17.8	12.1	161.7	4504	6915
T_9	155.0	200.1	17.3	12.4	165.5	4862	7236
T_{10}	160.5	216.5	18.2	12.6	169.0	4979	7516
SEd	8.02	8.64	0.91	0.63	7.27	223.4	349.3
CD (p=0.05)	16.84	18.15	NS	1.33	15.27	469.9	733.8
Second year							
T_1	138.1	168.2	15.5	13.1	142.2	3798	6467
T_2	141.2	172.1	15.9	13.5	147.5	3923	6914
T_3	146.5	179.2	16.2	13.9	150.3	4156	7123
T_4	145.2	175.2	16.0	13.5	155.4	3878	6789
T_5	150.7	181.3	16.4	14.1	163.0	4256	7321
T_6	157.5	188.3	16.8	14.8	168.4	4876	7954
T_7	158.9	180.6	17.0	14.7	160.5	4487	7043
T_8	165.2	182.4	17.4	15.1	166.7	4523	7233
T_9	168.2	190.2	17.5	15.3	170.5	4867	8076
T_{10}	172.3	195.6	17.8	15.5	174.0	5128	8234
SEd	7.84	12.9	0.62	1.12	5.96	412.9	314.9
CD (p=0.05)	16.48	NS	1.31	2.36	12.52	867.5	661.7

During first year the highest cob length, girth and weight were varied significantly due to various treatments. The highest cob length (18.2 cm), girth (12.6 cm) weight (169.0 g) and grain yield (4979 kg ha^{-1}) were observed in T10 which received the application of 100% RDF and basal application of TNAU micronutrient mixture @ 30 kg ha^{-1} as EFYM with foliar spray of 1% $FeSO_4$ at 30 DAS) and this was followed by T9 (T_7 + Foliar spray of 1% $FeSO_4$ at 30 DAS). In the second year the highest cob length (17.8cm), girth (15.5) and weight (174.0g) were registered in the same treatment.

The grain and stalk yield were recorded at harvest and the results revealed that there was significant difference among the treatments. The grain yield was ranged from 3151 to 4979 kg ha^{-1} and from 3798 to 5128 kg ha^{-1} in first and second year respectively. The highest grain yield was observed in T10 might be due to the combined 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. Similar trend was observed with regard to the stalk yield (Table 1). This might be due to the Organic matter improves iron availability by combining with iron, thereby reducing chemical fixation or precipitation of iron as ferric hydroxide. This reduction in fixation and precipitation results in higher concentrations of iron remaining in the soil solution, available for root absorption.

The treatment with the application of 100% RDF and basal application of TNAU MN mixture @ 30 kg ha^{-1} as EFYM with foliar spray of 1% $FeSO_4$ at 30 DAS (T8) has registered the highest soil DTPA- Fe content (5.4 mg kg^{-1}, 3.5 mg kg^{-1}) and Fe uptake (1.74 g ha^{-1}, 2.27 g ha^{-1}), while the least quantity was recorded in control at 45 DAS and at harvest respectively (Table 2). The combined addition of RDF, TNAU MN Mixture and Foliar spray of $FeSO_4$ might have increased the Fe content substantially. Moreover, it was stated that Fe contents increased in beans with the application of Fe (Karaman *et al*., 1997) [8]. 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) [11]. 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) [12] with the application of iron sulfate on the groundnut plants.

Table 2: The effect of iron fertilization on soil Fe and its uptake in calcareous soil

Treatments	First Year				Second Year			
	Soil DTPA-Fe (mg kg^{-1})		Fe uptake (g ha^{-1})		Soil DTPA-Fe (mg kg^{-1})		Fe uptake (g ha^{-1})	
	45 DAS	Harvest	45 DAS	Harvest	45 DAS	Harvest	45 DAS	Harvest
T_1	2.5	2.1	45.6	51.0	4.51	2.67	109.1	125.1
T_2	4.0	2.9	56.9	66.4	6.12	2.94	149.7	163.7
T_3	4.8	2.4	61.5	79.0	7.82	4.30	170.1	185.2
T_4	3.0	2.8	56.7	93.2	4.55	3.02	151.3	157.2
T_5	4.7	3.1	67.3	89.6	7.10	3.95	197.0	190.0
T_6	5.0	2.3	81.8	109.6	7.85	4.26	209.0	212.4
T_7	4.6	3.0	72.1	103.9	5.94	3.10	164.2	149.1
T_8	5.2	3.0	85.4	108.8	6.64	3.46	180.4	168.5
T_9	4.9	3.3	96.9	122.3	6.32	3.18	201.9	200.8
T_{10}	5.4	3.5	104.6	136.1	6.72	3.55	223.5	213.9
SEd	0.24	0.15	3.69	1.95	0.34	0.36	19.75	25.41
CD (p=0.05)	0.52	0.32	7.76	4.10	0.71	0.76	41.49	53.39

The different treatments exhibited significant difference in soil Fe content. Application of Fe SO_4 as enriched FYM showed highest soil Fe content in both stages of observation. The control recorded the lowest Fe content. The increased plant Fe uptake recorded in T10 might be due to the higher DMP.

Conclusion

Application of 100% RDF along with basal application of TNAU MN mixture @ 30 kg ha^{-1} as EFYM and foliar spray of 1% ferrous sulphate at 30 DAS resulted in highest growth, yield and yield parameters in hybrid maize in calcareous soil. Application of MN mixture was found to be better in increasing the yield and yield parameters of maize when compared to the application of $FeSO_4$. Application of $FeSO_4$ showed higher DTPA- Fe when compared to the application of TNAU MN mixture. Application of TNAU micronutrient 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 in calcareous soils.

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