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Studies on alleviating iron deficiency through iron fertilization in irrigated maize hybrid

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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 and calcareous soil. The effect of TNAU micronutrient (MN) mixture and $FeSO_4$ were studied by applying it as enriched form with and without $FeSO_4$ foliar spray. The highest grain yield was recorded in 100% RDF+ basal application of TNAU micronutrient mixture @ 30 kg ha^{-1} as EFYM + foliar spray of 1% $FeSO_4$ at 30 DAS. The stalk yield also followed the same trend as that of grain yield in both calcareous and non calcareous soil. Application of $FeSO_4$ enriched application showed higher Fe content in soil when compared to the application of TNAU micronutrient mixture either straight or enriched application in both calcareous and non calcareous soils. Application of TNAU micronutrient 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. Based on economics it was observed that the benefit cost ratio of 2.58 and 1.92 was obtained in the treatment with the application of 100% RDF+ Basal application of TNAU micronutrient mixture @ 30 kg ha^{-1} as EFYM + Foliar spray of 1% $FeSO_4$ at 30 DAS in non calcareous and calcareous soil respectively.

Keywords: Iron fertilization, non calcareous and calcareous soil, TNAU micronutrient mixture- EFYM

Introduction
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) [7, 8, 14]. Micronutrient deficiency limits plant growth and affects crop yield especially in calcareous soil Elham *et al*. (2014) [4]. 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) [2, 3] . 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 (Jeong & Guerinot 2009) [5]. 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) [11, 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) [12]. Organic manures, especially farmyard manure, have a significant role for maintaining and improving the chemical, physical and biological properties of soils. Zelalem Bekeko (2014) [15] 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 and noncalcareous soil.

Materials and methods
Field experiments were conducted in non-calcareous soil at Maize Research Station, Vagarai and in calcareous soil of farmers holding at Vagarai, Palani taluk, Dindigul district. The experimental soil type is non calcareous sandy loam with the initial soil of pH 7.65, EC 0.26 dSm^{-1} and organic carbon content of 0.39%.

Soil had low nitrogen (201.6 kg ha^{-1}), high phosphorus (23.6 kg ha^{-1}), high potassium (593.5 kg ha^{-1}) and DTPA- Fe content of 2.9 mg kg^{-1}. The initial soil pH 8.0 and EC of 0.49 dSm^{-1} respectively. Organic carbon content was 0.31%. Soil had low nitrogen (193.2 kg ha^{-1}), low phosphorus (9.2 kg ha^{-1}), high potassium (512.3 kg ha^{-1}) DTPA- Fe content of 5.1 mg kg^{-1} and free $CaCO_3$ content of 5.5%. For foliar application of 1% $FeSO_4$ and 0.1% citric acid was mixed together and used for spraying. Based on the research conducted during the past two years, the best performed five treatments were selected out of ten treatments for demonstration trial with the plot size of 38 x 4 m. The sowing was taken up with COHM 6 and Pioneer- 30V96 Maize hybrid in non-calcareous and calcareous soils respectively.

Treatment details are as follows.

T_1 - 100% RDF

T_2 - T_1+ $FeSO_4$ 37.5 kg ha^{-1} as EFYM + F.S of 1% $FeSO_4$ at 30 DAS

T_3 - T_1+ TNAU MN mixture @ 30 kg ha^{-1} + F.S. of 1% $FeSO_4$ at 30 DAS

T_4 - T_1+ TNAU MN mixture @ 30 kg ha^{-1} as EFYM

T_5 - T_1+ TNAU MN mixture @ 30 kg ha^{-1} as EFYM + F.S. of 1% $FeSO_4$ at 30 DAS

The design of the experiment was Randomized Block Design (RBD) with four 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

The plant height was the highest in the treatment T5 (100% RDF+Basal application of TNAU micronutrient mixture @ 30 kg ha^{-1} as EFYM + Foliar spray of 1% $FeSO_4$ at 30 DAS) in both non calcareous and calcareous soils. The highest cob length was recorded in T4 (100% RDF+ Basal application of TNAU micronutrient mixture @ 30 kg ha^{-1} as EFYM), while cob girth and weight were highest in100% RDF+Basal application of TNAU micronutrient mixture @ 30 kg ha^{-1} as EFYM + Foliar spray of 1% $FeSO_4$ at 30 DAS.However they were statistically on par with each other in both the soils (Table 1 & 2).

Table 1: The effect of iron fertilization on growth, yield and yield parameters in non Calcareous soil

Treatments	Plant height		Cob length (cm)	Cob girth (cm)	Cob weight (g)	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})
	45DAS	Harvest					
T_1	175.3	190.3	16.2	14.0	178.2	6014	8658
T_2	182.5	200.2	17.5	15.3	189.1	7322	9882
T_3	186.3	230.1	18.2	16.0	193.6	7642	10425
T_4	190.5	220.6	18.5	16.6	196.5	7864	10896
T_5	192.2	235.3	18.0	17.8	198.2	8231	11256
SEd	7.1	14.5	0.7	1.1	5.8	297	307
CD (p=0.05)	NS	31.6	NS	2.4	12.5	649	670

Table 1: The effect of iron fertilization on growth, yield and yield parameters in calcareous soil

Treatments	Plant height		Cob length (cm)	Cob girth (cm)	Cob weight (g)	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})
	45DAS	Harvest					
T_1	152.1	172.4	15.1	13.2	152.3	4002	6226
T_2	165.5	180.5	16.2	14.5	166.5	5242	8245
T_3	171.1	198.9	17.0	15.0	174.9	5825	8969
T_4	168.3	194.6	16.8	14.8	170.3	5796	8568
T_5	175.2	205.7	17.3	15.3	176.9	6112	9263
SEd	4.6	6.8	0.4	0.5	5.8	230	153
CD (p=0.05)	10.1	14.8	0.8	1.1	12.7	503	333

The iron fertilization significantly influenced the grain and stalk yield. The grain and stalk yield was highest in the treatment which received the application of 100% RDF+Basal application of TNAU micronutrient mixture @ 30 kg ha^{-1} as EFYM + Foliar spray of 1% $FeSO_4$ at 30 DAS) followed by 100% RDF+ Basal application of TNAU micronutrient mixture @ 30 kg ha^{-1} as EFYM and the lowest being in 100% RDF in both non calcareous and calcareous soils.

Table 3: The effect of iron fertilization on soil iron and iron uptake in non-calcareous soil

Treatments	Soil DTPA-Fe (mg kg^{-1})		Fe uptake (g ha^{-1})	
	45 DAS	Harvest	Grain	Straw
T_1	3.01	2.54	97.8	158.1
T_2	9.06	3.76	204.8	277.8
T_3	7.92	3.29	187.3	267.2
T_4	8.50	3.40	203.6	291.2
T_5	8.54	3.55	205.6	306.6
SEd	0.4	0.3	14.8	20.8
CD (p=0.05)	0.9	0.7	32.3	45.3

Table 4: The effect of iron fertilization on soil iron and iron uptake in calcareous soil

Treatments	Soil DTPA-Fe (mg kg^{-1})		Fe uptake (g ha^{-1})	
	45 DAS	Harvest	Grain	Straw
T_1	4.98	2.44	50.2	99.0
T_2	7.66	3.35	120.7	201.7
T_3	6.96	3.01	117.2	186.8
T_4	7.37	3.15	116.8	187.4
T_5	7.48	3.20	132.6	219.5
SEd	0.23	0.19	8.8	14.2
CD (p=0.05)	0.51	0.43	19.2	30.9

Application of $FeSO_4$ in enriched form resulted higher Fe content of 9.06 mg/kg, 3.76 mg/kg at 45DAS and at harvest respectively in non-calcareous soil when compared to the application of TNAU micronutrient mixture either straight or enriched application (Table 3 & 4). In calcareous soil application of Fe SO_4 as enriched FYM showed higher soil DTPA- Fe (7.66 mg/kg, 3.35 mg/kg) at 45 DAS and at harvest when compared to the application of TNAU micronutrient

mixture with and without enrichment. The control recorded the lowest Fe content. However the Fe uptake was found to be highest in T5 in both the soils. This might be increased DMP in grain and stalk at45 DAS and harvest and it was statistically on par with remaining treatments except T1. 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) [6]. 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) [9]. 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) [10] with the application of iron sulfate on the groundnut plants.

Table 5: Economics of cultivation of maize hybrid under different treatments

Treatments	Gross Return (Rs.)	Total cost of Cultivation (Rs.)	Net Return (Rs.)	Benefit Cost Ratio
Non Calcareous soil				
T_1	78182	38400	39782	2.04
T_2	95186	40256	54930	2.36
T_3	99346	41275	58071	2.41
T_4	102232	40100	62132	2.55
T_5	107003	41475	65528	2.58
Calcareous soil				
T_1	52026	38400	13626	1.35
T_2	68146	40256	27890	1.69
T_3	75725	41275	34450	1.83
T_4	75348	40100	35248	1.88
T_5	79456	41475	37981	1.92

Based on economics, it is observed that the benefit cost ratio of 2.58 and 1.92 was obtained in the treatment with the application of 100% RDF+ Basal application of TNAU micronutrient mixture @ 30 kg ha^{-1} as EFYM + Foliar spray of 1% FeSO4 at 30 DAS in non-calcareous and calcareous soil respectively (Table 5).

Conclusion

Application of 100% RDF along with basal application of TNAU micronutrient 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 both calcareous and non-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 $FeSO_4$. Application of $FeSO_4$ showed higher DTPA- Fe when compared to the application of TNAU MN mixture in both soils. 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 both the soils.

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