Original Research Article

EFFECT OF IRON FORMULATIONS ON THE PERFORMANCE OF MAIZE CROP

ABSTRACT

Chelated iron formulations are gaining importance due to their higher use efficiency and favourable effect on crop growth and yield. At present, chelated iron formulations prepared using synthetic chelating agents are used by farmers which are harmful to the ecosystem. Hence, an attempt made in the present study to develop new chelated iron formulations using citric acid, a naturally occurring organic acid. Newly developed TNAU Fe citrate (10.9 % Fe) formulation was tested in comparison with Ferrous sulphate and commercial Ferric citrate. Nine treatments replicated thrice in Randomised Block Design (RBD). The treatments included control (NPK alone), soil application (basal) of $FeSO_4$ @ 9.5 kg Fe ha^{-1}, TNAU Fe citrate and commercial Ferric citrate @ 0.95 and 1.9 kg Fe ha^{-1}, foliar spray of 1.0 % $FeSO_4$, TNAU Fe citrate and commercial Ferric citrate thrice on 30, 40 and 50 days after sowing (DAS). The results revealed that foliar application of Fe fertilizers outperformed soil application due to the calcareous nature of the experimental soil. Among the Fe formulations, foliar spray of 1% TNAU Fe citrate recorded highest yield attributes (cob length, no. of grains /cob, 100 grain weight), grain and stover yield, net income and B:C ratio.

Key words : *Iron chelates, Maize, Yield, Economics, Soil iron*

1. INTRODUCTION

The efforts of achieving self sufficiency in food production in India have been challenging. United Nations population report says that by the year 2050, world human population will reach 9.7 billion, India’s population is expected to overtake that of China will raise to 1.6 billion from the current level of 1.2 billion. A challenge for agricultural scientists is to feed the world population with nourishing food. Micronutrient deficiencies are major constraints in crop production in the present day agricultural programmes.

Fe is involved in many enzymatic transformations in plants, including the enzymes related to chlorophyll synthesis, and hence Fe deficiency results in characteristic chlorosis symptom. Fe is a structural component of porphyrin molecules. Fe deficiency in soil not only reduces the productivity but also reduces the concentration of Fe in the edible parts.

Therefore, Fe deficiency leads to nutritional problems in human beings, especially in the developing countries where cereals are the staple food.

"Ferrous sulphate which is the major source of iron to plants has the problem of getting converted in to unavailable forms and hence has lower use efficiency. Chelated forms of iron fertilizers showed higher use efficiency than sulphate forms and hence can be applied at 8 to 10 times lesser dose than their corresponding salts. In chelates, the metal is surrounded by organic molecules that it cannot react with other substances and converted in to insoluble forms"[15]. Vempati and Loeppert [1] observed that when compared to the inorganic form such as sulfates, chelates are most effective. The absorption of ions is enhanced by chelating agents. Alloway [2] reported that chelated fertilizers are widely used for foliar applications, compatible for tank mixing with many pesticide and fungicide formulations, but more expensive than inorganic compounds. Chelated form of fertilizers have many advantages over inorganic fertilizers but they are expensive and synthetic chelating agents are toxic to environment. Hence, in this study, new chelated Fe formulation using citric acid, a naturally occurring organic acid as chelating agent was developed and evaluated with maize crop.

2. MATERIALS AND METHODS

A field experiment was conducted at Eastern Block farm of Tamil Nadu Agricultural University, Coimbatore during 2019 to evaluate the effect of newly developed chelated Fe formulation on the performance of maize (TNAU Maize hybrid CO6) crop. Newly developed TNAU Fe citrate (10.9 % Fe) formulation was tested in comparison with Ferrous sulphate and commercial Ferric citrate. Nine treatments replicated thrice in Randomised Block Design (RBD). The treatments included control (NPK alone), soil application (basal) of $FeSO_4$ @ 9.5 kg Fe ha^{-1}, TNAU Fe citrate and commercial Ferric citrate @ 0.95 and 1.9 kg Fe ha^{-1}, foliar spray of 1.0 % $FeSO_4$, TNAU Fe citrate and commercial Ferric citrate thrice on 30, 40 and 50 days after sowing (DAS).

Soil Test Crop Response (STCR) based NPK fertilizer dose for Maize hybrid for a yield target of 9 t ha^{-1} was 259, 96 and 38 kg ha^{-1} N, P_2O_5 and K_2O respectively. NPK fertilizers and $ZnSO_4$ @ 25 kg ha^{-1} to correct the available Zn deficiency in the experimental soil were applied to all treatments. Necessary crop protection measures were taken up. Observations on yield attributes such as cob length (cm), number of grains cob^{-1}, 100 grain weight (g), grain and stover yield (kg ha^{-1}) were recorded. Five plants per plot was marked for taking observations such as cob length and average value expressed as cm. Five cobs per plot from the marked plants were selected for recording average number of grains cob^{-1}.

Grain and stover yield per plot was recorded and expressed as kg ha^{-1}. “Post harvest soil samples collected from field experiment were analyzed for DTPA-Fe as per the procedure developed” by Lindsay and Norvell [3]. “Economics of different treatments viz., net income and B:C ratio were worked out. The data recorded were subjected to statistical analysis as suggested” by Panse and Sukhatme[4].

3. RESULTS AND DISCUSSION

Table 1 lists the physicochemical characteristics of the soil used in the experiment. The experimental soil belongs to Periyanaickenpalayam series coming under the taxonomic classification fine, montmorillonitic, isohyperthermic, calcareous Typic Haplustert. The soil has a clay loam texture. experimental soil was calcareous, alkaline in reaction (pH 8.07) with permissible amount of soluble salts (EC 0.24 dS m^{-1}). The organic carbon content of the soil was low (4.79 g kg^{-1}). The available N, P and K content of the soil were low (134 kg ha^{-1}), medium (16.7 kg ha^{-1}) and high (657 kg ha^{-1}) respectively. With respect to micronutrients, the soil was deficient in DTPA-Zn (0.60 mg kg^{-1}), DTPA-Fe (2.27 mg kg^{-1}), DTPA-Cu (0.89 mg kg^{-1}) and sufficient in DTPA-Mn (5.08 mg kg^{-1}).

Table 1. Properties of Initial Soil Sample

pH		:	8.07
EC	dSm^{-1}	:	0.24
Organic Carbon	g kg^{-1}	:	4.79
Available N	kg ha^{-1}	:	134
Available P		:	16.7
Available K		:	657
DTPA-Fe	mg kg^{-1}	:	2.27
DTPA-Zn		:	0.60
DTPA-Mn		:	5.08
DTPA-Cu		:	0.89

3.1. Yield attributes and yield of maize

The treatment foliar spray of 1.0 % TNAU Fe citrate (T_8) registered significantly highest cob length of 20.6 cm which was on par with foliar spray of 1.0 % commercial Ferric citrate (T_9) (Table 2). The treatments soil application of 1.9 kg Fe ha^{-1} as TNAU Fe citrate (T_4) and as commercial Ferric citrate (T_6), soil application of 9.5 kg Fe ha^{-1} as $FeSO_4$ (T_2) and foliar application 1% $FeSO_4$ (T_7) recorded comparable cob length. Lowest cob length of 13.8 cm was observed in control (NPK alone - T_1) and it remained on par with soil application of 0.95 kg Fe ha^{-1} as TNAU Fe citrate (T_3) and as commercial Ferric citrate (T_5). Regarding number of grains per cob, the treatment foliar spray of 1.0 % TNAU Fe citrate (T_8) recorded significantly highest value of 292 followed by the treatment foliar spray of 1.0 % commercial Ferric citrate (T_9) which were statistically comparable. Lowest number of grains per cob (234) was observed in control (NPK alone - T_1). Soil and foliar application of Fe formulations did not have marked influence on the 100 grain weight of maize. However, the values varied from 34.9 to 40.2 g.

With respect to grain yield, foliar spray of 1.0 % TNAU Fe citrate (T_8) recorded significantly highest value of 7065 kg ha^{-1} followed by foliar spray of 1.0 % commercial Ferric citrate (T_9) (6904 kg ha^{-1}) which were on par. Statistically comparable grain yield was registered in the treatments soil application of 1.9 kg Fe ha^{-1} as TNAU Fe citrate (T_4) and as commercial Ferric citrate (T_6), soil application of 9.5 kg Fe ha^{-1} as $FeSO_4$ (T_2) and foliar application of 1% $FeSO_4$ (T_7). Lowest grain yield of 5857 kg ha^{-1} was observed in control (NPK alone - T_1) which was comparable with soil application of 0.95 kg Fe ha^{-1} as TNAU Fe citrate (T_3) and as commercial Ferric citrate (T_5).

Regarding stover yield, significantly highest value of 12583 kg ha^{-1} was observed with foliar spray of 1.0 % TNAU Fe citrate (T_8) followed by foliar spray of 1.0 % commercial Ferric citrate (T_9) which were statistically comparable. Stover yields recorded in the treatments soil application of 1.9 kg Fe ha^{-1} as TNAU Fe citrate (T_4) and as commercial Ferric citrate (T_6), soil application of 9.5 kg Fe ha^{-1} as $FeSO_4$ (T_2) and foliar application 1% $FeSO_4$ (T_7) were statistically on par. Lowest stover yield of 10279 kg ha^{-1} was noticed in control (NPK alone - T_1).

Table 2. Effect of Fe chelates on yield attributes and yield of maize

Treatments	Cob length (cm)	No. of grains/cob	100 grain weight (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T_1 - Control (NPK alone)	13.8	234	34.9	5857	10279
T_2 - 9.5 kg Fe ha^{-1} as $FeSO_4$	18.6	261	38.3	6403	11212
T_3 - 0.95 kg Fe ha^{-1} as TNAU Fe citrate	16.5	260	38.0	6225	11007

T_4 - 1.9 kg Fe ha^{-1} as TNAU Fe citrate	19.3	273	39.4	6638	11703
T_5- 0.95 kg Fe ha^{-1} as commercial Ferric citrate	15.9	252	37.7	6188	10934
T_6 - 1.9 kg Fe ha^{-1} as commercial Ferric citrate	18.8	266	38.9	6592	11674
T_7 - Foliar spray of 1.0 % $FeSO_4$ *	18.3	264	38.5	6307	11025
T_8 - Foliar spray of 1.0 % TNAU Fe citrate*	20.6	292	40.2	7065	12583
T_9 - Foliar spray of 1.0 % commercial Ferric citrate *	20.1	279	39.7	6904	12324
SEd	0.5	9	1.7	192	330
CD (P=0.05)	1.1	18	NS	400	688

*thrice on 30, 40 and 50 DAS

It was already reported by Ziaeian and Malakouti [5] and Abbas *et al.* [6] that iron fertilization significantly increased the yield attributes and grain yield of wheat. The best performance of foliar application when compared to soil application might be due to the calcareous nature of the experimental soil. Supremacy of foliar application of chelated fertilizers over soil application was already documentd by Guodong Liu et al. [7]. Wissuwa et al. [8] observed increased yield of crops with foliar application of Zn, Fe and Mn. Cakmak [9] reported that "foliar nutrition is an option where nutrient deficiencies cannot be corrected by soil application of nutrients". Kandoliya et al. [10] reported that "foliar nutrients usually penetrate the leaf cuticle or stomata, enters the cells facilitating easy and rapid utilization of nutrients, increases photosynthetic pigments, growth and yield of wheat". Sangeetha et al. [11] observed that Fe citrate treatment recorded the highest and significant values of fodder yield when compared to other types of chelates and $FeSO_4$. The results of this study are in line with the findings of Mansour et al. [12] and Alvarez Fernandez [13]. Effective utilization of Fe containing compounds such as Fe (III)-citrate by plant cells was already documented by Alvarez Fernandez et al. [14]. They reported that foliar applied Fe (III)-citrate penetrated the leaf, distributed within the plant and induced new growth re-greening in chlorotic tobacco plants.

3.2.Post harvest soil Fe status

Soil application of 1.9 kg Fe ha^{-1} as TNAU Fe citrate (T_4) registered significantly highest post harvest soil available Fe (2.51 mg kg^{-1}) (Table 3). Soil application of iron citrates recorded significantly higher post harvest soil available Fe than soil application of $FeSO_4$. Significantly lowest post harvest soil available Fe (1.68 mg kg^{-1}) was observed in control (NPK alone) which was comparable with foliar applied treatments. The results revealed that foliar application of iron fertilizers have not contributed to improve soil Fe status.

3.3. Economics of Fe formulations

Highest B:C ratio (2.55) and net income (Rs.75,485/-) were observed in the treatment foliar spray of 1.0 % TNAU Fe citrate (T_8) (Table 3). This might be attributed to the higher yield recorded in this treatment.

Table 3. Effect of Fe chelates on post harvest soil Fe and economics in maize

Treatments	Soil Fe (mg kg^{-1})	Net income (Rs.)	B : C ratio
T_1 - Control (NPK alone)	1.68	58013	2.30
T_2 - 9.5 kg Fe ha^{-1} as $FeSO_4$	2.01	65982	2.43
T_3 - 0.95 kg Fe ha^{-1} as TNAU Fe citrate	2.24	61846	2.31
T_4 - 1.9 kg Fe ha^{-1} as TNAU Fe citrate	2.51	67056	2.36
T_5- 0.95 kg Fe ha^{-1} as commercial Ferric citrate	2.06	55545	2.05
T_6 - 1.9 kg Fe ha^{-1} as commercial Ferric citrate	2.18	55049	1.91
T_7 - Foliar spray of 1.0 % $FeSO_4$ *	1.71	64137	2.39
T_8 - Foliar spray of 1.0 % TNAU Fe citrate*	1.74	75485	2.55
T_9 - Foliar spray of 1.0 % commercial Ferric citrate *	1.72	58621	1.94
SEd	0.09		
CD (P=0.05)	0.19		

*thrice on 30, 40 and 50 DAS

4. CONCLUSION

Foliar application of Fe fertilisers produced higher yields than soil application, which may be related to the calcareous composition of the experimental soil. The treatment foliar spray of 1% TNAU Fe citrate recorded highest yield attributes (cob length, no. of grains /cob, 100 grain weight), grain and stover yield, net income and B:C ratio. Foliar application of 1% of the TNAU Fe citrate thrice on 30, 40 and 50 days after sowing in maize crop registered 12.0 % increase in grain yield and 17.7% increase in net income over foliar application of 1% Ferrous sulphate+0.1% citric acid.

ABBREVIATIONS USED

RBD : Randomized Block Design

DAS : Days After Sowing

TNAU : Tamil Nadu Agricultural University

DTPA : Diethylene Triamine Penta Acetic Acid

$FeSO_4$: Ferrous Sulphate

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