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RESEARCH ARTICLE

A Iron Availability in Calcareous and Non Calcareous Soils as Influenced by Various Sources and Levels of Iron

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ABSTRACT

Iron availability in alkaline and calcareous soils is very much limited due to high pH and presence of the excess amount of carbonate and bicarbonate ions. Iron is though adequately present in soils, it is not always sufficiently available to plants due to their faster conversion into unavailable ferric (Fe^{3+}) forms. The present study was taken up to understand the availability of Fe in soils and its relationship with various soil properties. A laboratory experiment was conducted with two calcareous soils and a noncalcareous soil and incubated for 45 days with various levels (0, 5 and10 kg Fe ha^{-1}) and sources of Fe ($FeSO_4$ and Fe EDTA) on calcareous and noncalcareous soils. The results revealed that increasing levels of Fe either as $FeSO_4$ or Fe EDTA increased the availability in soils and higher availability was noted with the application of 10 kg Fe EDTA in all the three soils. A linear increase in the Fe availability was observed with the addition of Fe EDTA at 10 kg ha^{-1} up to 45 days while with the addition of 50 kg $FeSO_4$ ha^{-1} higher availability was noticed up to 30 days after incubation. Inclusion of amendments viz., 12.5 t FYM and 0.25 % Acetic acid though further improved the availability in all soils, the effect was much better with FYM than the acetic acid in calcareous soils than in noncalcareous soil. A strong negative correlation was observed between soil pH and calcareousness with DTPA Fe availability.

Keywords: *FYM, Acetic acid, Fe levels and sources, Calcareous soils, Fe availability*

INTRODUCTION

Iron is an essential nutrient for plants and serves as a cofactor for a wide variety of cellular processes, such as oxygen transport, cellular respiration, chlorophyll biosynthesis, thylakoid biogenesis and chloroplast development (Kobayashi and Nishizawa, 2012; Tanuja Poonia *et al*, 2018). The availability of Fe is severely limited in calcareous soils due to their low solubility at high pH and bicarbonate concentration which reduces the Fe uptake by inactivating the Fe in plants (Mortvedt, 1991; Najafi-Ghiri *et al.,* 2013). Hence, Fe-deficiency induced chlorosis is a serious problem resulted in the yield loss and quality of crop produces in many crops particularly in the calcareous soils (Kim and Guerinot, 2007; Zheng, 2010). It is also closely related to the prevalence of Fe-deficiency-induced anemia in human beings (Murgia *et al.,* 2012).

Amelioration of Fe deficiency in soils and plants was generally achieved through the use of inorganic Fe salts, Fe chelates, organic manures, etc. either through soil application or as a foliar spray which differs significantly in maintaining soil Fe availability. Addition of Fe chelates to calcareous soils was proved to be very effective in maintaining soil solution Fe and the efficacy was better with Fe-EDDHA, Fe EDTA and Fe-DTPA but the recovery of Fe from ferrous sulphate was negligible under high soil pH and calcareousness (Jaloud *et al.,* 2013; Faraz *et al.*, 2014; Sedigheh Safarzadeh *et al.,* 2018). Inclusion of organic manures proved to be beneficial in increasing the availability of Fe in soils and it was widely reported by many researchers (Ali *et al.,* 2007; Yunchen Zhao, 2009; Amin, 2018). Further the Fe availability significantly correlated with many soil properties particularly pH, carbonate and bicarbonate ions and organic carbon content which majorly controls the availability (Obrador *et al.,* 2007; Wang *et al.*, 2009; Wu *et al.,* 2010; Canasveras *et al.,* 2014; Mahendra Kumar *et al.,* 2017). Hence the present study was taken up to test the effectiveness of various levels and sources of Fe on Fe availability in calcareous and noncalcareous soils with and without amendments.

MATERIAL AND METHODS

An incubation experiment was conducted

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in the laboratory of Department of Soil Science and Agricultural Chemistry, TNAU, Coimbatore to investigate the iron availability over a period of time as influenced by various iron sources, levels and amendments in texturally varied calcareous and noncalcareous soils. Selected properties of the soils used in the experiment were given in table 1. The experiment was conducted with three soils having varied intensity of calcareousness *viz.*, red calcareous, red non calcareous and black calcareous soils with three levels of Fe (0, 5 and 10 kg ha^{-1}), two sources of Fe ($FeSO_4$, Fe EDTA) and two ameliorants (0.25% Acetic acid and 12.5 t Farmyard manure).

A hundred grams of processed soils were weighed separately into containers and mixed with the calculated quantities of $FeSO_4$, Fe EDTA and amendments. There were fifteen treatment combinations which were replicated thrice in a factorially completely randomized block design. The treatments were imposed as per the schedule and the experiment was conducted for 45 days, by maintaining the soil moisture at field capacity. Moisture corrections were carried out at alternate days on weight loss basis and continued to maintain the field capacity. Destructive soil sampling was carried out at 7, 15, 30 and 45 days after incubation and the samples were analyzed for various physico-chemical properties and DTPA Fe availability as per standard procedures (Lindsay and Norwell, 1978; Jackson, 1973; Piper, 1944).

Soil samples collected after specified incubation intervals were shade dried, gently powdered with a wooden mallet, sieved through 2 mm sieve and stored. The changes in pH, electrical conductivity, free $CaCO_3$ and DTPA Fe were assessed to understand the effect of amendments, Fe sources and levels on the Fe availability in calcareous soils. Statistical analysis was done in FCRD with three replications. All means and graphs were drawn with Microsoft Excel and compared using the least significant difference (LSD) at 5% level.

RESULTS AND DISCUSSION

Changes in physico chemical properties

Soil reaction (pH) and free $CaCO_3$ content in both calcareous and noncalcareous soils decreased with incubation period due to the addition of amendments and different levels and sources of Fe.

Table 1. Selected properties of the initial soils

Parameters	Red calcareous	Black calcareous	Red non calcareous
Textural class	Sandy Clay Loam	Sandy Clay Loam	Sandy Clay Loam
pH (1:2.5 soil : water)	8.62	8.51	7.20
Electrical Conductivity(dS m^{-1})	0.37	0.24	0.32
Organic carbon (g kg^{-1})	4.60	4.40	3.50
Free $CaCO_3$ (%)	11.8	14.6	4.50
DTPA Fe (mg kg^{-1})	5.11	6.06	8.73

A sharp decrease in pH was observed up to 45 days and application of FYM at 12.5t ha^{-1} further reduced the soil pH of both calcareous and noncalcareous soils and the mean values varied from 7.53 to 8.39, 6.52 to 7.55 and 7.64 to 8.33 in red calcareous, red noncalcareous and black calcareous soils respectively. Between the various sources and levels of Fe, higher reduction in pH was

Table 2. Effect of different sources and levels of Fe and amendments on the DTPA Fe availability in calcareous and non-calcareous soils

Amendments / Time (Days)	Fe sources (kg ha^{-1})	Red calcareous soil					Red non calcareous soil					Black calcareous soil				
		7.00	15	30	45.00	Mean	7.00	15.00	30.00	45.00	Mean	7.00	15.00	30.00	45.00	Mean
No amendment	Control	5.68	5.40	5.34	5.15	5.39	2.64	2.87	3.09	2.91	2.87	6.27	6.24	5.97	5.42	5.97
	25 kg $FeSO_4$	8.62	13.60	11.00	10.50	10.90	3.75	4.19	4.46	3.54	3.99	7.76	8.44	10.20	9.33	8.92
	50 kg $FeSO_4$	10.50	14.80	12.30	11.10	12.20	4.05	4.37	4.68	3.93	4.26	8.41	10.5	12.70	11.6	10.8
	5 kg Fe EDTA	8.06	13.00	14.60	13.90	12.40	3.40	3.95	4.54	4.61	4.13	7.45	7.35	11.20	11.8	9.46
	10 kg Fe EDTA	9.09	15.10	18.30	15.40	14.50	3.77	4.11	4.80	4.71	4.35	7.61	7.78	12.70	12.4	10.10
	Mean	8.40	12.40	12.30	11.20	11.20	3.52	3.90	4.31	3.94	3.92	7.50	8.06	10.60	10.10	9.06
FYM (12.5t)	Control	9.18	11.90	12.50	9.55	10.80	3.39	3.87	3.97	4.28	3.88	6.70	7.22	7.72	7.90	7.38
	25 kg $FeSO_4$	18.70	19.30	17.30	16.40	17.90	4.70	4.53	4.62	4.50	4.59	10.60	11.7	12.0	11.10	11.3
	50 kg $FeSO_4$	21.70	23.20	18.00	17.40	20.10	5.18	4.85	4.89	4.77	4.92	11.80	12.9	13.8	12.70	12.8
	5 kg Fe EDTA	17.50	23.50	25.40	20.80	21.80	4.31	5.04	5.49	5.73	5.14	11.40	13.4	14.4	15.10	13.6
	10 kg Fe EDTA	18.40	25.70	27.00	24.50	23.90	4.70	5.84	6.02	6.13	5.67	12.90	14.8	15.8	16.40	15.0
	Mean	17.10	20.70	20.00	17.70	18.90	4.46	4.83	5.00	5.08	4.84	10.70	12.00	12.70	12.60	12.00
Acetic acid (0.25%)	Control	8.35	7.50	6.68	6.17	7.17	3.30	3.54	3.66	3.26	3.44	6.53	6.92	6.48	6.05	6.50
	25 kg $FeSO_4$	9.99	12.70	11.70	10.30	11.20	4.13	4.42	4.83	4.41	4.45	6.83	7.97	7.63	7.32	7.44
	50 kg $FeSO_4$	11.40	16.60	15.00	14.70	14.40	4.63	4.81	5.19	4.68	4.83	7.27	8.53	7.90	7.68	7.85
	5 kg Fe EDTA	13.60	14.50	14.50	11.50	13.50	3.95	4.87	5.36	5.64	4.95	6.30	8.13	8.25	8.55	7.81
	10 kg Fe EDTA	14.70	17.00	18.90	15.30	16.40	4.24	5.16	5.63	5.87	5.22	7.15	8.72	8.85	9.23	8.49
	Mean	11.60	13.70	13.40	11.60	12.60	4.05	4.56	4.93	4.77	4.58	6.82	8.05	7.82	7.77	7.61
		S	A	F	T	SA	AxF	AxT	SxAxF	SxAxT		SxAxFxT				
	SEd	0.096	0.096	0.124	0.111	0.166	0.215	0.192	0.373	0.333		0.746				
	CD (P=0.05)	0.189	0.189	0.244	0.218	0.328	0.423	0.379	0.734	0.656		1.468				

noticed with the addition of 50 kg $FeSO_4$ than the Fe EDTA and the reduction was much pronounced in the presence of FYM. The values varied from 7.75 to 8.33 in red calcareous, 7.04 to 7.36 in red noncalcareous and 7.84 to 8.26 in black calcareous soils (Fig.1). A similar reduction in soil pH due to FYM and Fe sources was observed in calcareous soils by Roy and Abdul Kashem (2014). A sharp decrease in the free $CaCO_3$ content was also noted in the soils and the values varied from 7.77 to 10.4 per cent in red calcareous, 2.59 to 3.09 per cent in red noncalcareous and 10.5 to 13.4 per cent in black calcareous soils (Fig 2). Application of 12.5 t FYM gradually reduced the calcareousness of the soils than 0.25% Acetic acid.

Table 3. Effect of different sources and levels of Fe and amendments on the pH of calcareous and non-calcareous soils

Amendments / Time (Days)	Fe sources (kg ha^{-1})	Red calcareous soil					Red non calcareous soil					Black calcareous soil				
		7	15	30	45	Mean	7	15	30	45	Mean	7	15	30	45	Mean
No amendment	Control	8.53	8.36	8.28	8.25	8.36	7.29	7.25	7.40	7.63	7.39	8.37	8.43	8.47	8.30	8.39
	25 kg $FeSO_4$	8.39	8.23	8.03	7.86	8.13	7.23	7.17	7.30	7.39	7.27	8.20	8.27	8.30	8.23	8.25
	50 kg $FeSO_4$	8.23	8.07	7.99	7.80	8.02	7.07	6.98	7.10	7.13	7.07	8.13	8.17	8.10	8.04	8.11
	5 kg Fe EDTA	8.30	8.13	8.00	7.96	8.10	7.11	7.20	7.27	7.38	7.24	8.24	8.23	8.17	8.08	8.18
	10 kg Fe EDTA	8.18	8.06	7.96	7.85	8.01	7.03	6.97	7.17	7.12	7.07	8.17	8.18	8.06	7.89	8.07
	Mean	8.33	8.17	8.05	7.94	8.12	7.15	7.11	7.25	7.33	7.21	8.22	8.26	8.22	8.11	8.20
FYM (12.5t)	Control	8.39	8.22	7.90	7.92	8.11	7.31	7.17	7.31	7.55	7.34	8.23	8.33	8.22	8.27	8.26
	25 kg $FeSO_4$	8.18	8.02	7.99	7.78	7.99	7.18	7.12	7.20	7.26	7.19	8.07	8.03	7.93	7.98	8.00
	50 kg $FeSO_4$	8.02	7.86	7.65	7.84	7.84	7.12	7.00	7.13	7.19	7.11	7.82	7.79	7.71	7.83	7.79
	5 kg Fe EDTA	8.09	7.93	7.77	7.67	7.86	7.07	7.01	7.34	7.40	7.20	7.97	7.87	7.72	7.86	7.85
	10 kg Fe EDTA	7.97	7.81	7.62	7.53	7.73	6.96	6.92	7.27	7.30	7.11	7.89	7.76	7.64	7.69	7.75
	Mean	8.13	7.97	7.79	7.75	7.91	7.13	7.04	7.25	7.34	7.19	7.99	7.96	7.84	7.93	7.93
Acetic acid (0.25%)	Control	8.45	8.31	8.10	8.07	8.23	7.33	7.21	7.34	7.56	7.36	8.30	8.32	8.27	8.21	8.28
	25 kg $FeSO_4$	8.27	8.11	7.93	7.85	8.04	7.26	7.11	7.30	7.34	7.25	8.14	8.07	8.10	8.06	8.09
	50 kg $FeSO_4$	8.11	7.95	7.85	7.75	7.92	6.97	7.23	7.23	7.25	7.17	7.96	8.03	7.92	7.97	7.97
	5 kg Fe EDTA	8.18	8.02	8.00	7.94	8.03	7.30	7.13	7.23	7.36	7.26	8.16	7.99	7.97	8.15	8.07
	10 kg Fe EDTA	8.06	7.90	7.87	7.81	7.91	7.05	7.02	7.18	7.26	7.13	8.07	7.87	7.75	8.02	7.93
	Mean	8.22	8.06	7.95	7.88	8.03	7.18	7.14	7.26	7.36	7.23	8.13	8.05	8.00	8.08	8.07
		S	A	F	T	SA	AxF	AxT	SxAxF	SxAxT		SxAxFxT				
	SEd	0.025	0.025	0.032	0.029	0.043	0.056	0.050	0.098	0.087		0.196				
	CD(P=0.05)	0.049	0.049	0.064	NS	0.057	0.111	NS	0.192	NS		NS				

Here also a higher reduction in calcareousness was associated with the application of 50 kg $FeSO_4$ followed by 10 kg Fe EDTA. Reduction in soil free $CaCO_3$ due to the addition of amendments and iron

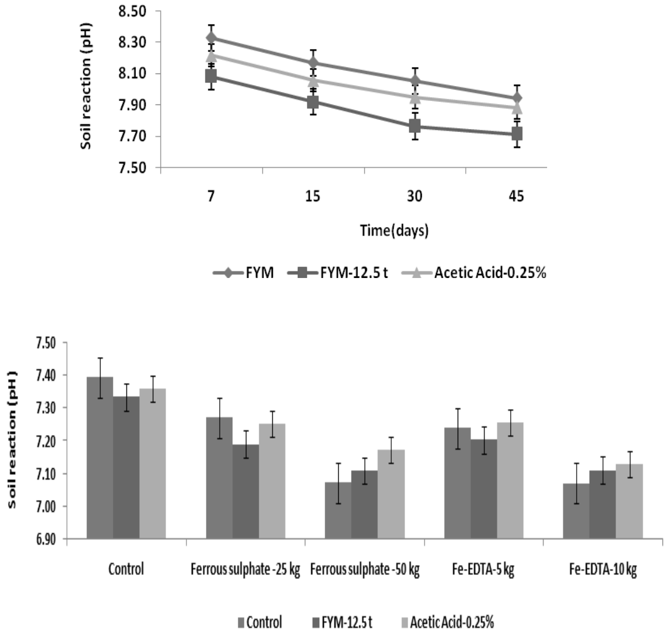

Figure 1. Effect of different Fe sources, levels and amendments in influencing the pH of calcareous and non calcareous soils (Error bars in figure shows standard deviation of means)

sources was marked in calcareous soil than in noncalcareous soil. A similar reduction in calcareousness due to the addition of FYM was reported by many researchers (Heydarnezhad *et al*., 2012; Ahmed, 2013; Chen *et al*., 2016).

DTPA Fe availability

The DTPA Fe availability increased with increasing time intervals up to 30 days in calcareous soils and declined thereafter (Fig. 3). The values varied from

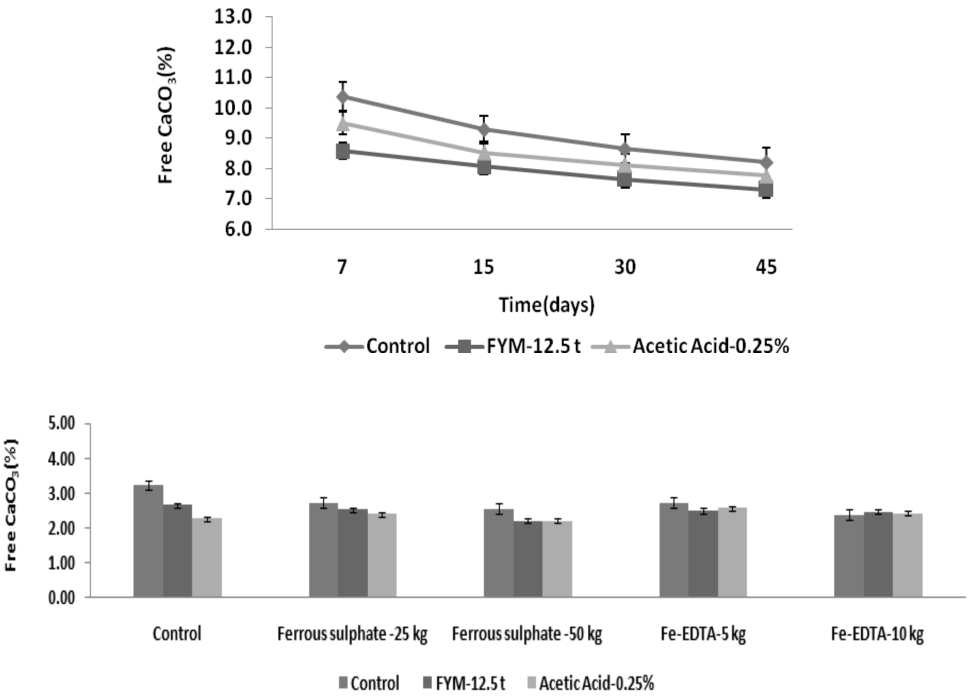

Figure 2. Effect of different Fe sources, levels and amendments on free $CaCO_3$ content in calcareous and non calcareous soils (Error bars in figure shows standard deviation of means)

8.6 to 20.7 mg kg^{-1} in red calcareous, 3.5 to 5.0 mg kg^{-1} red noncalcareous and 6.8 to 12.7 mg kg^{-1} in black calcareous soils (Table 2). Increasing levels of Fe addition through both the sources increased the Fe availability and the highest DTPA Fe status was recorded with the addition of 10 kg Fe chelate and the effect was well pronounced with the inclusion of 12.5 t FYM (4.84 to 18.9 mg kg^{-1}) followed by 0.25

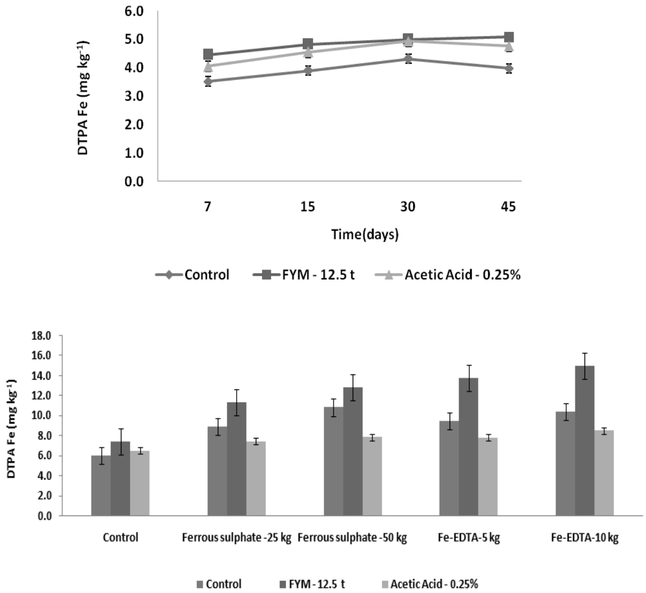

Figure 3. Effect of different Fe sources, levels and amendments on DTPA Fe availability (Error bars in figure shows standard deviation of means

% acetic acid (4.58 to 12.6 mg kg^{-1}) and un-amended control (3.92 to 11.2 mg kg^{-1}).In the calcareous soils, the combined application of 10 kg Fe chelate + 12.5 t FYM sustained higher Fe availability for 30 days in red calcareous and 45 days in black calcareous soils. Significant increase in soil Fe availability might be due to mineralization and release of Fe from organic matter during decomposition and also due to the addition of iron-containing fertilizers. Further addition of organic materials might have enhanced the microbial activity in the soil which consequently released the Fe from complex organic substances (Chen *et al.,* 2016; Tanuja Poonia *et al.*, 2018).

Higher Fe availability was also related to the change in soil properties over a period of time due to the addition of amendments and Fe sources. This was evident from the negative relationship between pH, EC (r = -0.63**), DTPA Fe (r = -0.92**) and free $CaCO_3$ content of soils (r = 0.84**). The above relationship suggested that iron availability decreased with an increase in soil pH and free $CaCO_3$ content probably due to the formation of insoluble iron hydroxide and iron carbonate at higher pH and free $CaCO_3$. A similar relationship was observed by Canasveras *et al.* (2014) and Mahendra Kumar *et al.* (2017).

CONCLUSION

To conclude, a linear increase in DTPA Fe extractability was observed with incubation period in all three soils and the highest availability was associated with the addition of 10 kg Fe EDTA ha^{-1} followed by 50 kg $FeSO_4$ ha^{-1}. Inclusion of FYM at 12.5 t ha^{-1} and 0.25 % Acetic acid considerably improved the Fe availability in soils and the better effect was registered with FYM. Higher Fe extractability was noted up to 30 days in the red calcareous soil while in black calcareous soils the release was linear up to 45 days. A negative correlation between soil pH and calcareousness was observed on the Fe availability in the soils.

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