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Effect of Moisture Regimes and Amendments on Iron Transformation in Acid Soils

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An incubation experiment was conducted at Department of Soil Science and Agricultural Chemistry, Directorate of Natural Resources Management, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu during 2017-18, with an objective to study the iron transformation and changes in soil reaction in acid soils of Ambasamudram series (*Aquic Haplustalf*). There were two levels of $FeSO_4$ (0 and 50 kg ha^{-1}), two sources of amendments viz., lime (as per requirement @ 22.5 t ha^{-1}) and FYM @ 12.5 t ha^{-1}, with three moisture regimes viz.,continuous submergence, alternate wetting and drying, and field capacity. The experiment was conducted for 60 days and the soil samples were drawn at 15, 30, 60 days after incubation, analyzed for pH, DTPA Fe, water soluble Fe and exchangeable Fe. Liming @ 22.5 t ha^{-1} was found to be effective for bringing the acidic pH to near neutral. Available iron and water soluble iron was noticed to be higher under submerged condition than compared to alternate wetting drying and field capacity moisture regimes. The recovery of Fe in various pools revealed that 25 to 33 percent of Fe entered into water soluble + exchangeable form at 60 days after incubation.

Key words: Acid Soil, Exchangeable iron, DTPA iron, Soil pH, Water soluble iron

Soil acidity is a serious constraint for crop production in many regions of the world including India. Acid soils have a pH less than 6.5 in the top layer covers 30 per cent of global arable land acounting for 3950 million hectares (Uexkull and Mutert, 1995). Out of total acidic soil exist in our country, 25 million hectares have pH below 5.5 and 23 million hectares have a pH range of 5.6 to 6.5 (Mandal and Hazra, 1997). Majji et al. (2012) reported that out of the total geographical area of India, strongly acid soil and moderately acidic soil accounts for 6.24 and 24.41 million hectares respectively. Which is 1.9 and 7.4 per cent of the total geographical area of the country. Majority of these soils (≥ 95%) are concentrated in the northeastern region of India, whereas, 65 percent of soil has extreme acidity (pH less than 5.5), Sharma and Singh (2002).

Iron as a fourth most copious element plays a vital role in earth bio-geo-chemistry (Borch et al., 2009). Additionally to its abundance within the earth's crust, iron in aerobic soils is found principally within the form of insoluble Fe3+ oxides or hydroxides that decrease iron bioavailability to plants (Stein et al., 2014). The low land rice soils under submergence create an anaerobic condition which results in low redox potential and pH (Gotoh and Patrick, 1974) and under such conditions Fe2+ is released into the soil solution from its otherwise less soluble forms and hence available to the plants at concentrations that's normally be toxic (Jeffery, 1961; Ponnamperuma et al., 1967). However, iron toxicity may occur in submerged soils as a consequence of high amounts of reducible iron, low pH, and low cation-exchange capacity (Becker and Asch, 2005). In fact, iron toxicity is the most widespread nutritional disorder that affects wetland rice production (Dobermann and Fairhurst, 2000).

Keeping the soils continuously flooded throughout the growth period, generally recommended for successful cultivation of rice. But due to uncertainty in rainfall or lack of adequate irrigation water, rice fields in tropical countries are often subjected to varying moisture regimes, resulting in changes in the intensity of reducing condition developed in the soil. This may influence the transformation of nutrients particularly iron and manganese and consequently their availability in soil.The organic matter, texture and calcium carbonate content also restricts the iron availability. In this context the changes in iron availability, soil reaction and iron transformation were investigated under three moisture regimes viz., continuous submergence, alternate wetting and drying, and field capacity with application of different amendments (FYM, lime and 2 levels of FeSO4).

Material and Methods

Bulk soil collection and characterisation

Acid soils (**s**urface soil samples) in bulk from the plough layer (15 cm) was collected from the farmer's field at V.K.Puram, Ambasamudram, Thirunelveli district, situated in the southern zone of Tamil Nadu at 77º38' East longitude and 8º71'North latitude. Sub sampling was done from the collected bulk soil samples. Air dried and gently broken to pass through 2 mm sieve. Again the sieved samples were thoroughly mixed and analysed for various physico

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chemical properties by adopting standard analytical procedures.

The soil was red, acidic, silty clay belonging to the soil series Ambasamudram (Aquic Haplustalf). The soil reaction was acidic (pH 3.98) and free from salinity (0.08 dS m^{-1}).The soil was very low in organic carbon content (1.16 g kg^{-1}), low in available nitrogen (210 kg ha^{-1}), medium in available phosphorus (13.2 kg ha^{-1}), and potassium (260 kg ha^{-1}). With reference to micronutrients, the soil was medium in DTPA Zn (1.53 mg kg^{-1}) and DTPA Mn (3.92 mg kg^{-1}), high in DTPA Fe (222 mg kg^{-1}) and DTPA Cu (3.90 mg kg^{-1}).

Treatment Details

Incubation experiment was conducted with the acid soil during 2017-18, with two levels of $FeSO_4$ (0 and 50 kg ha^{-1}), two sources of amendments viz., lime (as per requirement @ 22.5 t ha^{-1}) and FYM @ 12.5 t ha^{-1}, under three moisture regimes viz.,continuous submergence, alternate wetting and drying, and field capacity. Above eighteen treatments were replicated thrice in a completely randomized blocks design. The field capacity (FC) of the soil was measured by pressure plate apparatus and maintained throughout the study period. 100 grams of processed soil was weighed separately into polythene containers and respective amendments were imposed and the experiment was conducted for 60 days. Moisture corrections were carried out at alternate days on weight loss basis and continued.

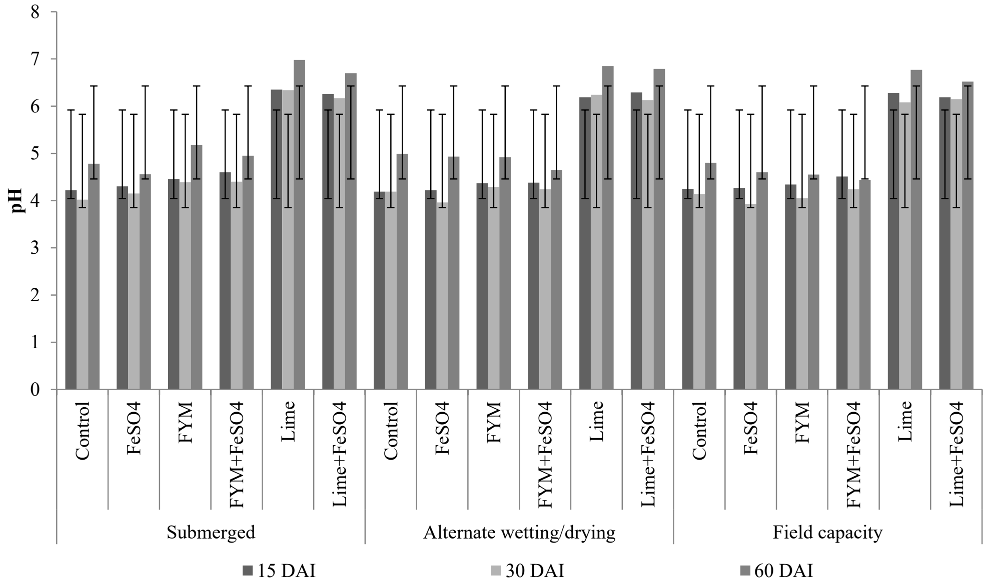

Fig.1(a). Soil pH

Soil sampling and analysis

Destructive soil sampling was done at 15, 30 and 60 days after incubation and the soil samples collected were analyzed for pH, DTPA iron, water soluble iron and exchangeable iron. The soil pH was estimated in soil: water suspension (1:2.5) as given by Jackson (2005). The soil available Fe was analyzed using DTPA extract and followed by Atomic Absorption Spectrophotometer estimation (Lindsay and Norvell, 1978). Water soluble and exchangeable iron was analyzed by sequential extraction method proposed by Tessier *et al.* (1979). The data on various observations recorded during the course of investigation were analyzed statistically by adopting the procedure described by Panse and Sukhatme (1967). The data were subjected to Fisher's method of analysis of variance and the level of significance used in F tests was P = 0.05. The critical differences were calculated at 5 per cent probability level whenever F value was found to be significant.

Results and Discussion

Soil pH

The soil pH increased from 3.99 to 6.98 due to the addition of various treatments after 60 days (Fig.1a). An initial increase in pH at 15 days and a drop at 30 days and further increase after 60 days was noticed with various moisture regimes. Continuous submergence registered higher pH than alternate wetting and drying followed by field capacity. This might be subsequently due to soil reduction and largely due to reduction of iron (Ponnamperuma et. al., 1967). Among the various treatments lime addition as per lime requirement considerably increased the soil pH by 75% irrespective of moisture regimes and incubation periods. Inclusion of FYM and FeSO4 did not show much influence on the pH and little improvement was observed in all situations. This could be ascribed to replacement of H+ ion by Ca ion in the exchangeable complexes with addition of lime (Abichandani and Patnaik, 1961).

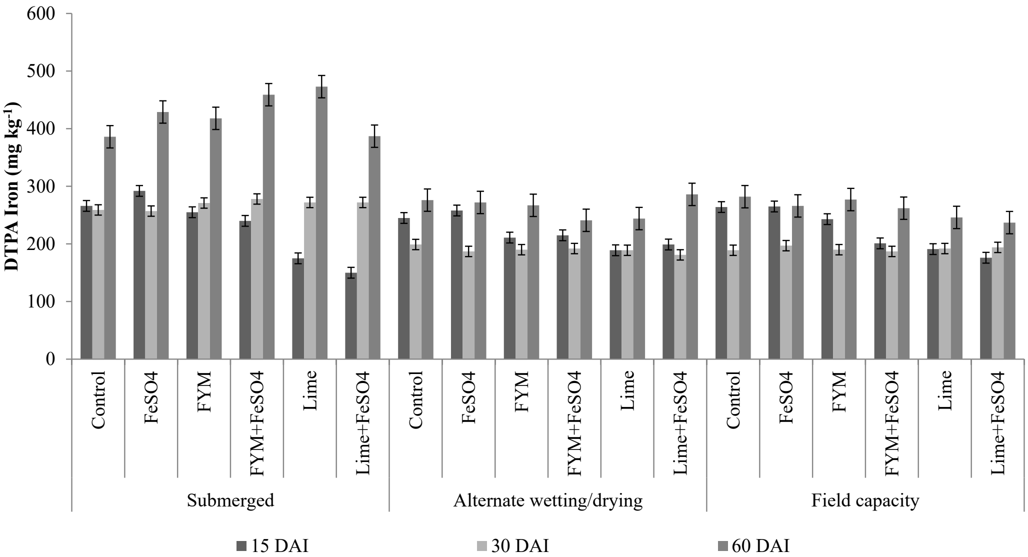

Fig.1(b). Available iron

Soil available Fe

Higher DTPA Fe was found in continuous submergence followed by field capacity, alternate wetting and drying (Fig.1b). Higher iron availability was found at 60 days after incubation. An initial increase in Fe availability was reported at 15 days after incubation whereas a slight decrease in availability of Fe was noticed after 30 days. This

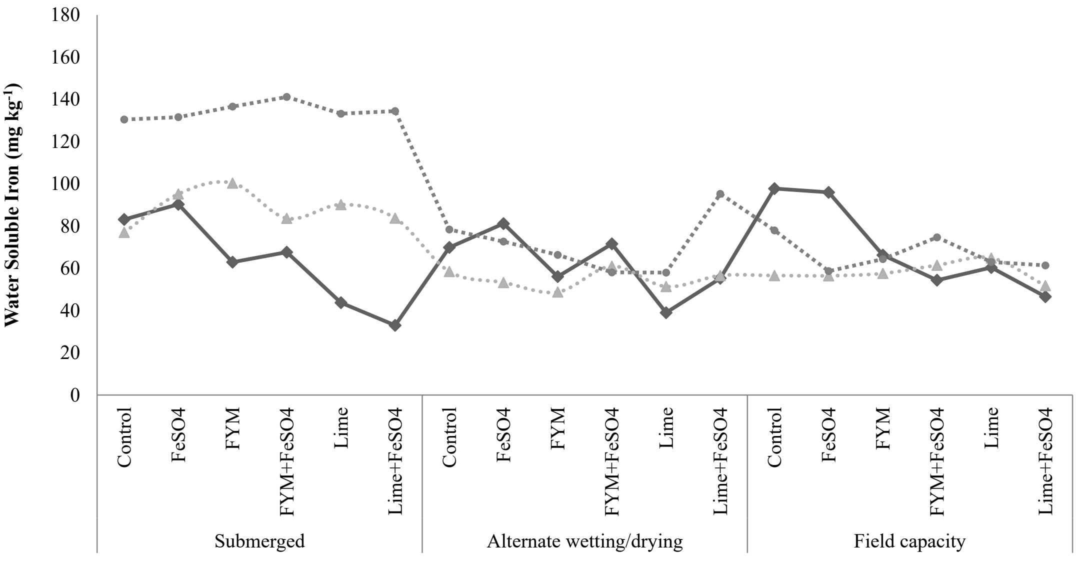

Fig.1(c). Water soluble iron

might be due to reduction of Fe^{3+} in to Fe^{2+} form under reduced condition. The increase in water soluble iron and exchangeable iron might contribute to the higher available iron (Mandal and Mitra, 1982). The Fe availability among the treatments followed the order: $FeSO_4$ > control > FYM > FYM + $FeSO_4$ > lime > lime + $FeSO_4$. Inclusion of FYM showed a 2 fold increase in Fe availability. This might be due to the decomposition of organic matter, which in turn increased the microbial population and hence, the partial pressure of carbon dioxide in the soil, preventing the precipitation as well as further oxidation of the ferrous iron formed under the reduced condition (Mandal and Mitra, 1982).

Water soluble iron

The water soluble Fe varied from 33 to 141 mg kg $^{-1}$ during 60 days period of incubation (Fig.1c). Higher water soluble iron was found under continuous submergence followed by field capacity and alternate wetting & drying. Increase in water soluble iron fraction was noticed with increase in days of incubation under continuous submergence. Whereas, no marked difference was found under other moisture regimes except a slight drop in water soluble Fe at 15 days after incubation. A high water soluble Fe under submerged condition over all other moisture regimes might be due to the reduction of ferric iron to ferrous form. A similar trend was reported by (Mandal and Mitra, 1982). They also indicated that

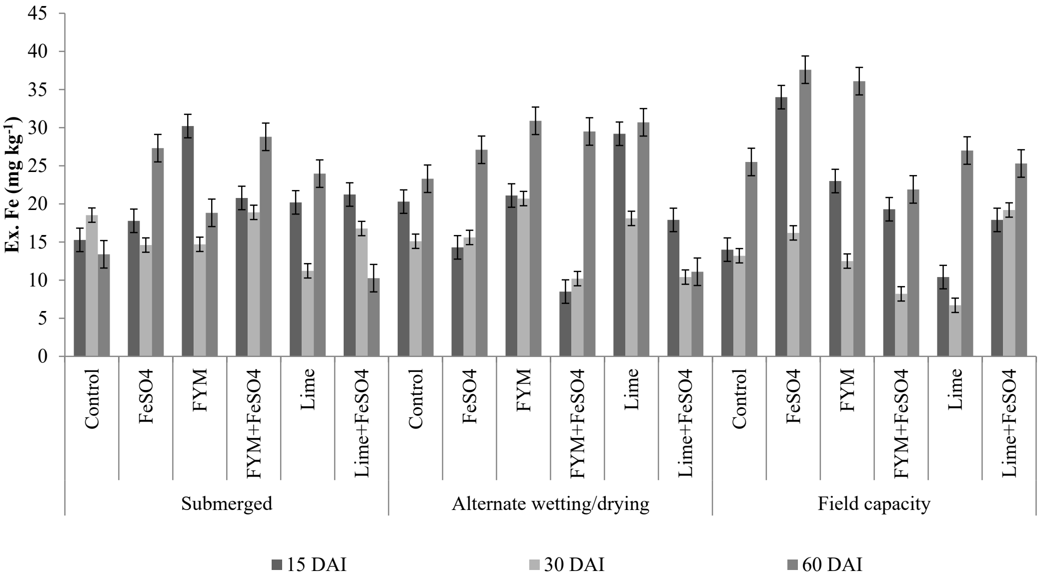

Fig.1(d). Exchangeable iron

water logging caused increase in the content of WS form of iron in all soils, especially in acid soils. Among the treatments $FeSO_4$ application showed a marked increase in WS Fe might be due to the presence of readily soluble form of iron, whereas inclusion of FYM reported next to the $FeSO_4$ in terms of WS Fe. This might be due to the presence of organic acids which facilitated the availability of fixed iron fraction (Mandal and Mitra, 1982).

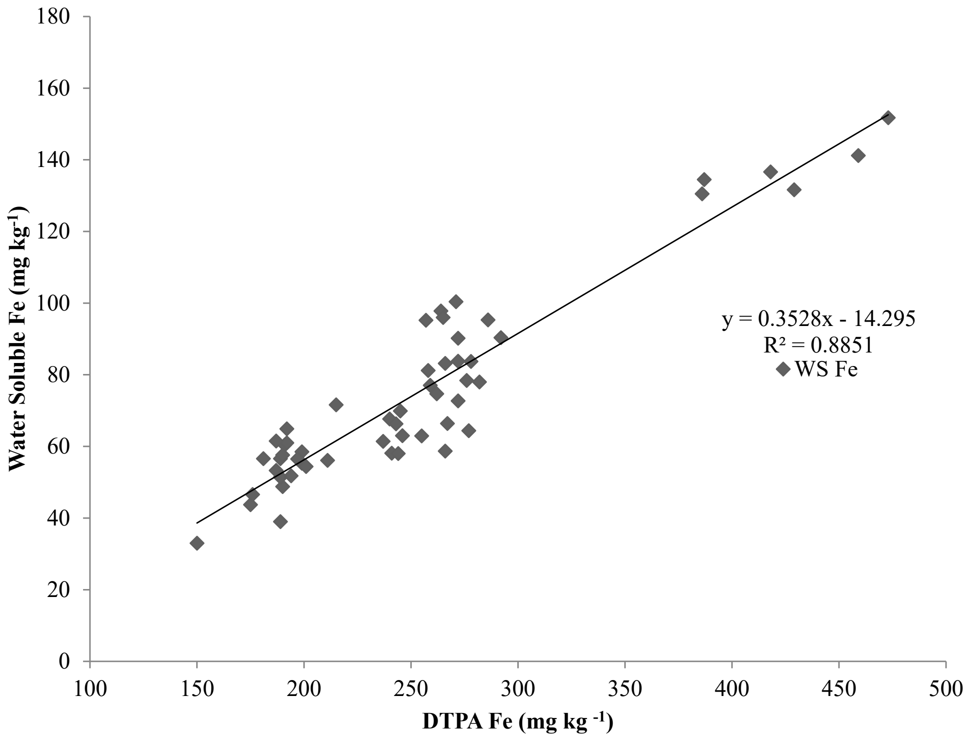

Fig. 2(a) Relationship between DTPA vs water soluble Fe

Exchangeable iron

The exchangeable Fe of the incubated soil found to be higher under field capacity followed by alternate wetting and drying, and continuous submergence (Fig.1d). The Exch. Fe content in the incubated acid soil varied from 8.5 to 37.6 mg kg^{-1} during the 60 days of period. A higher content 14% of available iron fraction found to be associated with exchangeable form under field capacity, whereas it was reported to be less under all other moisture regimes. Among the treatments, the lowest exchangeable Fe was recorded with inclusion of FYM under continuous submergence and field capacity. This might be due to higher transformation of exchangeable iron fraction in to soluble form, as organic acids and microbial activities facilitated by organic matter decomposition in turn increased solubilisation of the iron fractions (Mandal and Mitra, 1982).

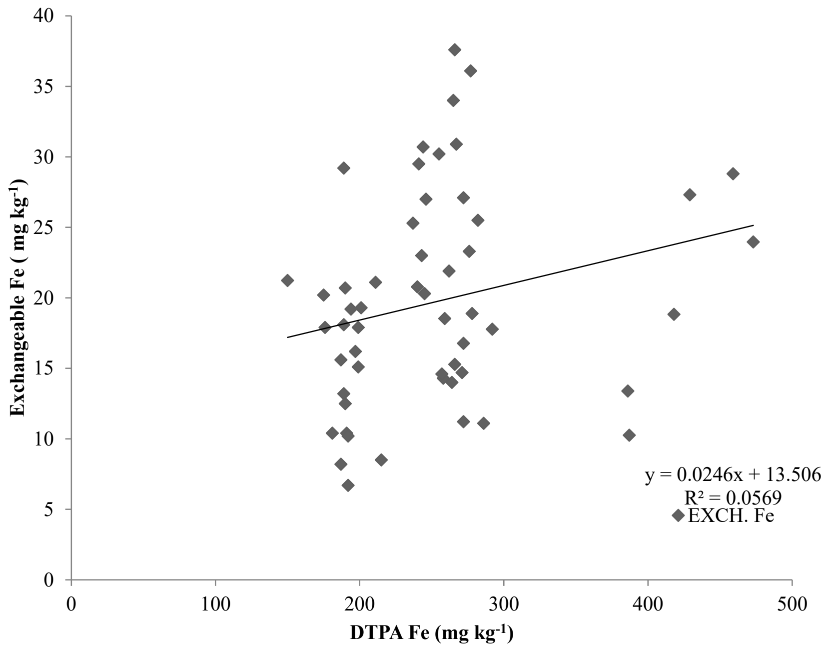

Fig. 2(b) Relationship between DTPA Fe vs exchangeable Fe

Relationship of water soluble and exchangeable iron with available iron

Under the acidic conditions, higher water soluble Fe fraction was found to be associated with higher Fe availability (Fig.2a). A linear relationship was existed between these two fractions viz. water soluble and available iron. The contribution due to exchangeable Fe was found to be very meagre as depicted in the Fig.2b. A close observation of these two results concluded that water soluble fraction contributed more towards Fe availability than the exchangeable fraction under all conditions.

Conclusion

From the study it is concluded that continuous submergence increased soil pH. Liming @ 22.5 t ha-1 was found to be effective for bringing the acidic pH to near neutral. Available iron and water soluble iron was found to be higher under submerged condition than compared to all other moisture regimes. Liming was significantly associated with decreased iron availability followed by FYM inclusion. The recovery of Fe in various pools revealed that around 25 to 33 per cent of Fe entered into water soluble + exchangeable form at 60 days after incubation and water soluble fraction contributed more towards Fe availability than exchangeable iron under all conditions.

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