AMELIORATION EFFECT OF POTASSIUM ON IRON TOXIC SOILS OF ORISSA

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Iron as an essential plant nutrient was established by E. Griss (1843). Being required in small quantity for growth and development of plant, it is considered as a micronutrient but becomes harmfull when present in large quantity in soil. Atomic structure gave it two oxidation states i.e. Ferrous (Fe^{2+}) and Ferric (Fe^{3+}). Ferric form when get reduced is converted to ferrous form in soil and absorbed by plant.

$$Fe^{3+} + e^{-} = Fe^{2+}$$

Insoluble soluble

Excess availability of soluble ferrous ion in the rhizosphere becomes toxic.

Various edaphic and climatological factors assigned to the cause of iron toxicity are grouped as:-

i) Soil Type

ii) Land situation

iii) Climate

iv) Soil properties.

i) Soil Type: Ferruginous red and lateritic soils are rich in iron. Parent rocks and minerals contain high quantity of iron. In Orissa lateritic, red and mixture of red are dominant group of soils which occupy about 50.75 % of total geographical area. Upon disintegration and weathering of parent material iron becomes available in soil solution phase (Sinha et al., 1962).

ii) Land situation: The concentration of soluble Fe is more in mid and low land situation (Ponnamperuma, 1955). Under submerged and anaerobic condition, Fe^{3+} accepts electron and get reduced to soluble Fe^{2+}. Apart from in situ Fe, accumulation of soluble irosn from upper pediment through interflow gets deposited in mid and lowland under a toposequence or rolling topography (van Breemen and Moorman, 1978). Upwelling water table brings soluble iron and enriches the rhizosphere with it leading to iron toxicity in soil.

iii) Climate: Temperature is one of the important environmental factors causing iron toxicity (Ponnamperuma et al., 1967). Low temperature brings late but high and persistent concentrations of water soluble iron. This toxicity is a result of one or more environmental constraints (Benckizer et al., 1982). Torrential rainfall for a prolonged period may reduce iron toxicity by washing out the soluble iron whereas a well distributed normal rainfall may create high concentrations of soluble iron in the rhizosphere.

IV) Soil properties: There is a strong correlation exists between physical, chemical and mineralogical properties of soil with iron toxicity. Light textured soil helps in internal flow of soluble iron from adjacent upland to mid and low land. Heavy textured soil contains more active iron and restricts percolation loss of in situ soluble iron (Panabokke, 1975). Rising water table during wet season under anaerobic condition brings soluble Fe from subsurface to surface layer (Sahrawat, 2003). Chemical properties like soil reaction, salt content, nutrient availability and cation exchange capacity along the soil column have significant relationship with development of toxic levels of iron in soil.(Ponnamperuma et.al., 1955, , Tanaka and Yashida, 1970, Mohanty and Patnaik, 1977).

The soil with acidic pH and high active Fe content when get reduced toxic level of Fe is produced (Tanaka and Yoshida, 1970). This typical problem of wet land rice is a physiological complex nutrient disorder and the deficiency of several other nutrients especially K, P, Ca, Mg, Si and Zn (Benckizer et al., 1982, Sahu, 2001). Mohanty and Patnaik, 1977, observed that the potassium deficiency aggravated Fe toxicity. High salt content helps in production of soluble iron through increasing solubility of iron compounds. Soil minerals bearing iron act as the source of soil iron. Rice soils under go seasonal reversible oxidation reduction process that favour the formation of amorphous and poorly crystallized minerals which are relatively more soluble (Randhawa et al., 1978). A study of fine sand fraction (0.1-0.25 mm) of control section soils of four profiles under iron toxic group of Orissa revealed that, chlorite, garnet, magnetite and siderite were four important species of iron bearing minerals. Chlorite was the dominant one followed by magnetite, garnet and siderite in sequence (Nayak, 2008).

Table Fe minerals in fine sand (%) of profile soils

Sl.No.	Name of minerals	Ideal formula	Bhubaneswar *Inceptisols*	Chiplima *Inceptisols*	Gajmara *Alfisols*	Duburi *Alfisols*
1	Chlorite	$Fe(Si_4O_{10})\ OH_8$	3.0	2.0	4.0	4.0
2	Garnet	$Fe_3\ Fe_2\ (SiO_4)_3$	1.0	0.5	1.5	1.0
3	Magnetite	$FeFe_2O_4$	2.0	1.5	0.5	3.5
4	Siderite	$Fe\ (CO_3)$	0.5	0.5	1.0	1.0

Iron is present in many forms in soil. The form and its quantity in soils play an important role in determining its availability to crop plat (Viet, 1962). These forms are i) Total and ii) Available comprising exchangeable and water soluble. All forms are in dynamic equilibrium with each other. The profile distribution of total iron as well as reducible iron (Fe-O) showed an increasing trend from 3.8 to 7.2 and 0.52 to1.90 per cent respectively from surface to bottom layers. But DTPA –Fe showed the reverse trend with respect to depth of the profiles. The value varied from 110 mg/kg to 460 mg/kg.

Table 2: Profile distribution of different forms of iron

Horizon	Total Fe (%)	Fe-0 (%)	DTPA-Fe (mg/kg)
1st	3.8-4.5	0.52-0.84	272-400
2nd	4.8-5.3	0.98-1.23	166-384
3rd	5.6-6.6	1.21-1.48	151-380
4th	6.3-7.2	1.48-1.90	110-372

Very few workers reported about the extent of iron toxic area in Orissa. Mitra and Sahu, 1992 reported that there is potential area of 72 thousand ha where as acute suffering area is 40 thousand ha as per Sarkar, 2005.

The critical concentration of soluble Fe causing toxicity varies from situation to situation (Sahrawat ,2003).It is reported that a wide range of soil solution concentration of 30-1500 mg/L soluble iron where as a concentration of 10-1680 mg/L in culture solution can causes toxicity (Dev and Mandal, 1967). The wide range of soluble iron is due to concentration of other irons, soil properties, environmental factors and varietal tolerance (Ponnamperuma, 1978).

Toxicity symptoms are manifested in soil, leaf, root, grain and crop field. Floating of brickish red oily scumes on surface particularly near the corner and bonds is a common feature of the soil (Sahu et al. 1992). In leaves, tiny brown spots appear in older leaves. Roots turn bushy, brownish to black and absence of white root is a common feature. The seed coat becomes tinged with small brown spots. Toxicity may cause 10-100 % crop loss.

A critical analysis of 88 iron toxic surface soil samples comprising 12 districts of Orissa revealed that, soils were acidic having low organic matter, deficient in N, P and K but very high content (> 100 ppm) of Fe .

Table3: Location from where iron toxic surface soils collected

Sl.No.	District	Block	Soil	DTPA-Fe(mg/kg)
1	Khurda*	Bhubaneswar	6	328.4-558.3
			7	
		Khurda	5	
			8	
2	Puri	Delanga	7	222.2-446.3
3	Nayagarh	Khandapada	6	201.5-261.6
4	Jajpur*	Danagadi	10	400.2-569.5
5	Dhenkanal*	Dhenkanal	5	244.4-258.5
6	Keonjhar	Baspal	8	160.7-215.2
7	Balasore	Nilgiri	4	133.6-159.9
8	Koraput	Semiliguda	5	125.7-144.8
9	Malkangiri	Kalimela	3	105.1-129.6
10	Baragarh	Attabira	4	110.9-136.2
11	Mayurbhanj	Rairangpur	4	138.5-141.4
12	Sambalpur*	Dharkauda	6	160.2-174.4
			88	110.9-569.5

* District where soil profile was studied.

Correction of this specific problem of soil can be accomplished by agronomic or varietal or chemical or combination of multiple methods. The pH is corrected through liming. The activities of microbe's are depressed through fresh cowdung and K. The excess soluble iron is chelated by application of organics. The use of oxidants is some of the chemical amelioration measures. Apart form these, supplementing deficient nutrients like K, Ca, Mg, Zn and organics are considered as suitable chemical strategies to combat this problem.

Amelioration of Fe toxic soils through application of K is a well established approach in most part of the Globe. This is also established by various researches in Orissa. In a pot experiment comprising of graded doses of K and Fe, Sahu and Mitra, 1992 observed that the dry matter yield of rice was increased with increasing dose of K which ranged from 4.06 to 4.46 g/pot whereas increasing dose of Fe reduced it (Table 4).

Table 4: INTERACTIVE EFFECT OF GRADED DOSES OF K & Fe ON DRY MATTER YIELD OF RICE (g/pot)

Levels(mg/kg)	Fe-0	Fe-50	Fe-100	Fe-200	Fe-300	Fe-400	mean	Increase over control(%)
K-0	7.86	7.95	5.75	1.05	0.99	0.56	4.06	-
K-30	7.05	8.00	6.27	1.54	1.05	0.60	4.23	4.2
K-60	7.89	8.16	6.75	2.00	1.07	0.61	4.41	8.6
K-90	7.88	8.20	6.79	2.10	1.21	0.80	4.46	9.8
mean	7.67	8.08	6.39	1.67	1.07	0.64		
CD(5%) k-0.15	Fe-0.18	kxFe-.036						

Table 5: UPTAKE OF NUTRIENTS

K dose (mg/kg)	K uptake(kg/ha)	Fe/K (ratio)
K-0	63.4	7.7
K-30	77.2	7.02
K-60	81.2	6.17
K-90	81.7	5.81
	CD (5%)	4.05

The uptake of K increased with increasing K dose from 63.4 kg/ha to 81.7 kg/ha. The ratio of Fe/ K went on decreasing from 7.7 to 5.81 with increasing dose of K indicating that K has antagonistic effect on Fe uptake(Table-5).

Table 6: EFFECT OF GRADED DOSES OF K ON SCORE VALUE &YIELD OF RICE(Kharif)

K-level kg/ha	Score value		Grain yield (q/ha)		Increase over control(%)		
	Jaya	Mahsuri	Jaya	Mahsuri	Jaya	Mahasuri	Mean
0	7-9	2-3	13	18	-	-	-
40	7	1-2	14	22	7.7	22.2	14.9
80	5	1-2	19	23	46.2	27.8	37.0
120	5	1	22	26	69.2	44.4	56.8
160	3	1	24	29	84.6	61.1	72.8
CD(5%)	K-2.5	V-1.0	Kxv-1.5				

In another field experiment at Bhubaneswar, the effect of graded doses of K on score value and grain yield of rice cv.Jaya (s) and Mahsuri (T) taken during kharif was studied and found that, with increasing dose of K, score value was reduced but the yield was increased (Table 6).

Table7:CONTENT OF IRON (mg'kg)IN DIFFERENT PARTS OF RICE CULTIVARS

K-levels	Leaf (max. tillering)		Grain		Straw	
	Jaya	Mahsuri	Jaya	Mahsuri	Jaya	Mahsuri
0	3396	1765	161	117	1305	983
40	3122	1330	221	111	1098	789
80	2421	1085	137	107	958	621
120	1775	702	130	103	800	522
160	1069	380	106	96	607	383
mean	2365	1052	151	107	954	641

Table 8:EFFECT OF GRADED DOSES OF K ON YIELD OF RICE(Rabi)

K- level kg/ha	Grain yield (q/ha)		Increase over control(%)
	Pathara	Parijat	Mean
0	4.9	8.0	-
40	11.5	15.2	106.9
80	13.6	17.3	139.5
120	18.2	20.5	200.0
160	22.7	24.2	263.5
Mean	14.2	17.0	

Rice cultivar Jaya was proved to be more prone to Fe toxicity than Mahsuri which was ascertained by score value and yield data .The increase of grain yield over control varied from 14.5 to 72.85%. This value increased with increasing K-doses. Analyses of Fe content at various parts like leaf, grain and straw showed that with increasing K-doses the Fe content decreased. The Fe content in leaf at maximum tillering stage was maximum followed by straw and grain. The values of above parameters were more in case of Jaya than Mahsuri confirming the differential varietal tolerance towards the toxicity (Table7).Above treatments were repeated during rabi season taking rice genotypes like Pathara (S) and Parijat (T) as test varieties and grain yield showed the same trend as seen during kharif. But the increase of grain yield over control varied from 106.9 to 263.5 per cent indicating a better response during rabi than kharif (Sahu et al., 2001).

The efficacy of K for ameliorating the toxic effects of Fe was compared with other sources through pot and field experiments taking Pathara (S) and IR-36 (T) varieties of rice in an acidic, low fertile, light textured soil with high available iron (Table9). It was found that K @ 80 kg/ha was the best treatment followed by lime, fresh cowdung, fly ash, Zn and others in sequence (Nayak and Sahu, 2008).

Table 9: Yield of rice as influenced by K & other sources

Treatment	Pot g/pot		Field (q/ha)		Yield increase over control(%)
	Pattare	IR-36	Pattare	IR-36	Mean
Control	15.90	18.71	10.2	16.3	-
Lime (pms)	23.85	30.96	19.3	26.8	73.96 II
ZnSO4,7H2O	19.80	25.37	15.4	25.2	53.2
Fly ash	23.30	30.82	18.6	26.1	68.67
MnSO4	20.13	25.52	16.1	24.6	53.58
K2O	24.10	31.60	19.9	27.5	78.86 I
FYM	20.18	29.55	17.5	24.8	59.62
Poultry manure	20.16	29.89	18.2	25.5	64.90
Fresh cow dung	23.05	30.30	18.9	26	69.43 III
Mean	20.64	28.08	17.12	24.75	-
CD(5%)	Chem-3.46 var.-1.63 cxv=4.9		Chem-2.04 var.-0.96 cxv=2.9		

The experiments clearly indicated that K has ameliorative effect on Fe toxicity. The mechanism of this reduction is either due to

I. Development of root oxidation power,

II. Fe excluding power of roots,

III. Supplementing K deficiency or

IV. Lethal action on microbes.

The K increases the root oxidation power which converts soluble Fe^{2+} to insoluble Fe^{3+} in rhizosphere (Tanaka & Yoshida, 1970).

Benckizer et al.(1982),clearly mentioned that K increases Fe excluding power of root. It depends on root permeability which increases at k deficiency. Lack of k enhances production of low molecular weight metabolites rather than higher weight. The deficiency of k also increases metabolic leakage by which low weight metabolites like soluble sugar, amide and amino acid exudes. As a consequence density and activity of facultative, obligat anaerobic bacteria increases causing higher demand for O_2 and use Fe^{3+}oxides as a hydrogen accepter for ATP formation. This reductive process increases Fe^{2+} production. In the other hand, adequate quantity of k produces higher weight molecules which prevent root exudation and entry of soluble iron inside by decreasing root permeability. Apart from it, K has lethal action on microorganisms responsible for depletion of O_2 and production of electrons. Application of K @ 80 kg/ha helps in meeting the plant k requirement and reducing Fe toxicity in rice under Orissa condition.

REFERENCES:

Benckizer, G., Ottow, J.C.G.; Santiago, S. and Watanabe, I. (1982) Physicochemical characterization of iron toxic soils in some Asian countries. IRRI Res. Paper series- 85, IrRI, Manila , Philippines.

Mitra, G.N.; Sahu, S.K. and Dev, G. (1990) Potassium chloride increases rice yield and reduces symptoms of iron toxicity. BetterCrops Int. 12: 14-15.

Mohanty, S.K.and Patnaik, S. (1977) Effect of submergence on the chemical change in different rice soils.The kinetics of K, Ca and Mg. Acta Agronimica, Acad. Sci. Hungery, 26:187-192.

Nayak, R.K. (2008) Studies on iron toxicity in relation to rice nutrition in soils of Orissa. Ph.D. thesis submitted to Visva-Bharati, Santiniketan, and West Bengal, India

Panabokke, C.R.(1975). Problem rice soils of Srilanka Res. paper at IRRI conference, April21-24, 1975 IRRI, Manila Philippines.

Ponnamperuma, F.N. Bradfield, R. and Peech, M. (1955) Physiological disease of rice attributed to iron toxicity. Nature, 175: 265.

Ponnamperuma, F.N.; Tiance, E.M. and Loy, T. (1967) Redox equalibria in flooded soils-I – The iron hydroxide system. Soil Sci 103: 374-382.

Ponnamperuma,F.N. (1978). Electrochemical changes in submerged soils and the growth of rice. Soils and Rice, IRRI, Manila, Philippines, 421:441.

Randhawa, N.S., Sinha, M.K.and Takkar, P.N. (1978) Micronutrients, Soils and Rice, Irri, Manila, Philippines: 231-256.

Sahrawat, K.L. (2003) Iron toxicity in wet land rice. Occurrence and management through integration of genetic tolerance with plant nutrition. J. Indian Soc.Soil Sci. 51(4): 409-417.

Sahu, S.K.and Mitra,G.N. (1992) Iron-Potassium interaction of nutrient balance in rice. J. Potassium Res. 8(4): 311-319.

Sahu,S.K.,Sandha, B. and Dev, G.(2001) Relationship between applied potassium and iron toxicity in rice. Int. Rice Res. News 26(2): 52-53.

Sahu,S.K.; Dev, G. and Mitra,G.N. (2001) Iron toxicity of rice as affected by applied potassium in lateritic soils. J. Res. OUAT, 19(1,2): 62-67.

Sarkar, A.K.(2007) Managing natural resources for increasing Agrl. Production in Eastern India, Proc. Training Course , Dept. of Soils, Punjab Agrl. University, Ludhiana.

Tanak, A. and Yoshida,S.(1970) Nutritional disorders of rice plant in Asia. Bult. No.10, IARI, Manila, Philippines.

Van Breemen, N. and Moormann, F.R.91978) Iron toxic soils, Soil and Rice, IRRI, Manila, Philippines: 781-800.

Viets, F.G.(1962) Chemistry and availability of micronutrients. J. Agric. Food Chem. 10: 174-178.