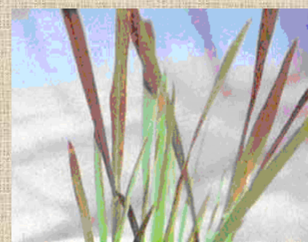

AMELIORATING EFFECTS OF POTASSIUM ON IRON TOXICITY IN SOILS OF ORISSA

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OUAT, BHUBANESWAR

This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Iron toxic soils

- **Iron toxicity is a problem associated primarily with rice crop grown on iron rich low land red and laterite soils.**
- **Under these conditions Fe^{+++} is reduced to Fe^{++}, which is absorbed by rice plant in larger quantities and causes Fe-toxicity.**
- **Other crops grown on such soils also suffer from iron toxicity and consequent yield loss.**

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Predisposing factors for iron toxicity

- Low lands adjacent to uplands. There is lateral flow of soluble iron from uplands to low lands, which enriches its iron content to toxic levels.
- Lower temperature and high rainfall
- Coarse texture and high water table
- Acidic pH
- Poor nutrient status (K,P,Ca,Mg, Zn,Si)
- High salt content

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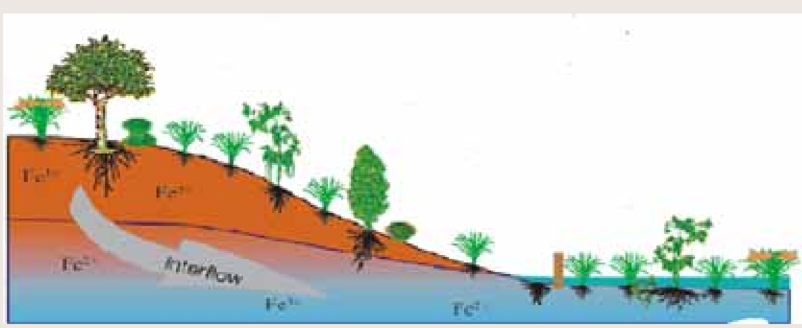
Land situations for manifestation of acute iron toxicity



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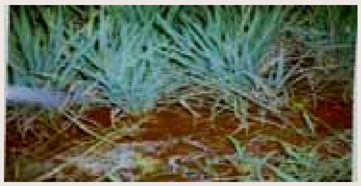
Symptoms of iron toxicity

Floating brickish red scums on surface



Tiny brown spots on lower lraves

Bushy brown roots, absence of white roots

Shy tillering, reduced growth, short panicle, yield reduction 10-100%

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Why were we interested in problem of iron toxicity?

- **The Research Farm, where we conduct field trials at Bhubaneswar is located on laterite soils.**
- **Late Dr. B. N. Sahu, a senior Agronomist reported(1968) bronzing of rice leaves caused probably by iron toxicity.**
- **The Plots of LTF Experiment (rice-rice crpping system), started in 1972 adjacent to an upland showed symptoms of iron toxicity, confirmed by soil and plant analysis.**
- **A detailed study on iron toxicity was initiated.**

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Iron content of soils of Orissa

- **Soils of Orissa are in general rich in iron (DTPA-Fe: 8.2-356.0ppm.)**
- **Red and laterite soils, which constitute 70% of the soils of Orissa contain 17.8-356ppm of DTPA-Fe**
- **Iron toxic soils, which show visual symptoms of toxicity contain 105.1-569.5ppm DTPA-Fe**

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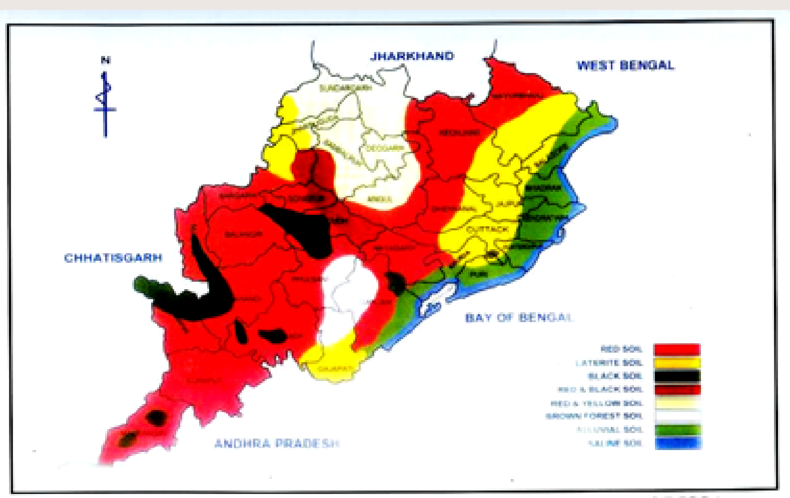
Occurrence of Red and laterite soils in Orissa



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Characterization of iron toxic soils of Orissa

(Av.of 88 samples collected from 12 districts of the State)

Chemical composition

Texture	pH (1;2)	Org. C ($g\ kg^{-1}$)	N $mg\ kg^{-1}$	P $mg\ kg^{-1}$	K $mg\ kg^{-1}$
SL-C	4.6-5.8	2.6-6.5	42.0-145.0	3.0-12.0	21.5-80.5

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Characterization of iron toxic soils of Orissa

(Av.of 88 samples collected from 12 districts of the State)

Chemical composition

Ca	Mg	Fe	Zn	Mn	Cu
c mol (p+) kg^{-1}		(DTPA) mg kg^{-1}			
1.7-4.8	0.8-2.5	105.1-569.5	0.55-1.85	2.8-110.4	0.38-4.06

DTPA Fe < 4.5 mg kg^{-1} is rated as low, 4.5- 9 medium and > 9 high

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Profile distribution of different forms of iron

A total of four pedons were exposed. The following Table gives results of One of the Test pedon)

No. &Name of Pedon	Depth (cm)	Total Fe (%)	Fe-O (%)	DTPA-Fe (mg kg^{-1})
Bhubane-swar	0-17	3.8	0.52	428
	17-33	4.8	0.98	398
	35-53	6.3	1.23	384
	53-120	5.8	1.78	372

Classification of iron toxic soils of Orissa

Ped-on No.	Order	Sub-Order	Great Group	Sub-Group	Family	Series
1.	Inceptisol	Ustepts	Haplu-stepts	Aquic Haplu-stepts	Coarse, loamy,mixed , perthermic	Bhubaneswar
2.	Inceptisol	Ustepts	Haplu-stepts	Fluven-tic Haplu-stepts	-do-	Chiplima
3.	Alfisol	Ustalfs	Rhodu-stalfs	Kanh-aplic Rhodu-stalfs	-do-	Gajamara
4.	Alfisol	Ustalfs	Paleu-stalfs	Kandic Paleu-	-do-	Duburi

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Estimated area under Iron Toxic Soils

- Soils with DTPA-Fe > 100mg kg^{-1} and showing visual symptoms : 52000 ha
- Nutrient index (NI) for Fe (NI < 2.0 def., 2.01-2.33 adequate, 2.33-2.66 moderately high, > 2.67 high)
- 29 out of 30 districts of the state have NI > 2.67.
- State average of NI is 2.66. (Jena *et al.* 2008)
- 22 districts out of 30 have mean DTPA-Fe, 50-100mg kg^{-1}.
- Soils with latent iron toxicity (50-100 mg kg-1) without showing visual symptoms but causing yield loss probably covers a very large are.(~1.5-2.0 million ha), especially in a scenario, where fertiliser consumption is 53.2 kg ha^{-1}. (N:P:K= 34:12:7)

Studies on Fe-K interaction

- **Some of the treatments of LTF-Experiment showed that Fe-toxicity symptoms could be alleviated by application of higher doses of K.**
- **<u>A systematic study was initiated through</u>**
- **Solution culture studies**
- **Pot culture Experiments**
- **Field Trials**

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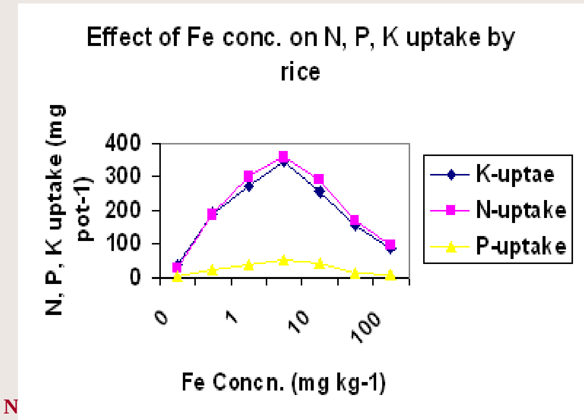
Effect of Fe conc. on N,P,K uptake by rice (Solution culture studies)

Plants harvested after exposing 21days old seedlings for 40 days in graded doses of Fe



N … **g kg^{-1}**

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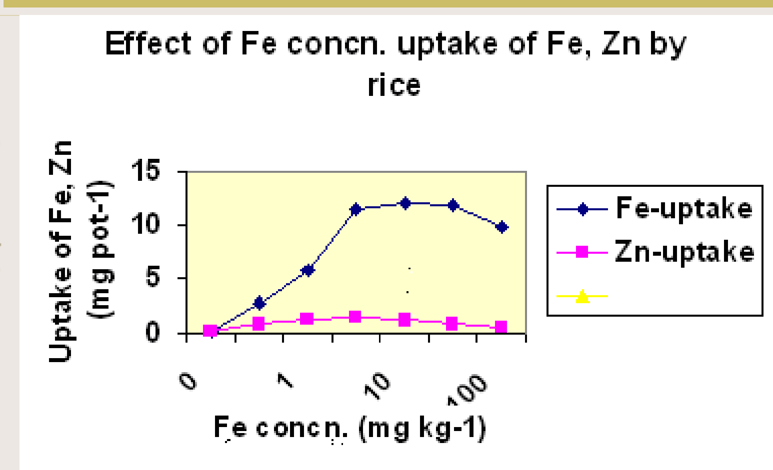
Effect of Fe conc. on uptake of Fe and Zn (Solution culture studies)



Fe and Zn uptake also tended to decrease beyond 10 mg kg-1

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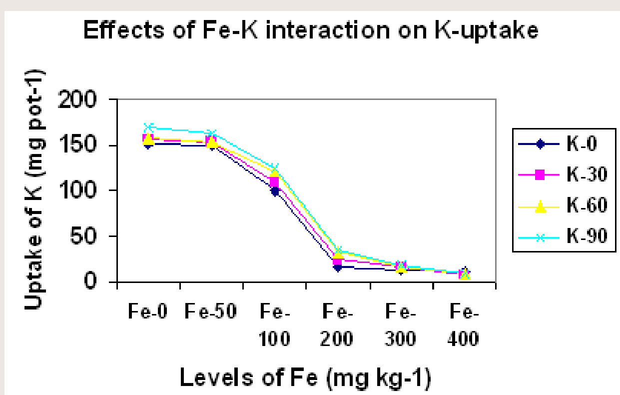
Iron-potassium interaction
(Pot culture studies)

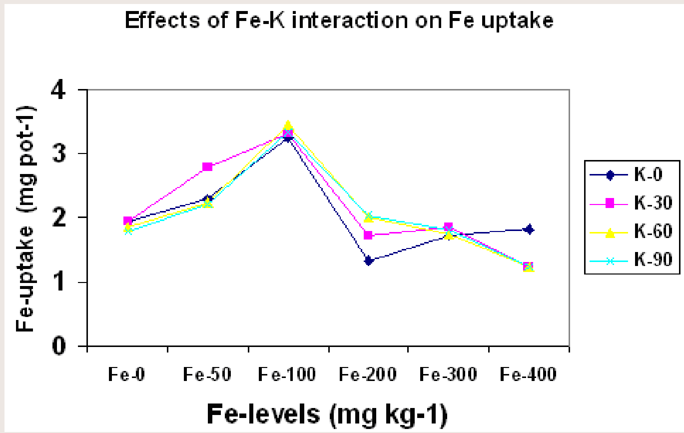
Effects of Fe-K interaction on dry matter yield of 40 days old rice plants (g pot^{-1}) (pH of soil used=5.4, DTPA-Fe=79 mg kg^{-1})

Levels (mg kg-1)	Fe-0	Fe-50	Fe-100	Fe-200	Fe-300	Fe-400	Mean
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**
K-60	**7.89**	**8.16**	**6.75**	**2.00**	**1.07**	**0.61**	**4.41**
K-90	**7.88**	**8.20**	**6.79**	**2.10**	**1.21**	**0.80**	**4.46**
mean	**7.67**	**8.08**	**6.39**	**1.67**	**1.07**	**0.64**	
CD(0.05) K= 0.15 Fe = 0.18 K X Fe = 0.36							

Effects of Fe-K interaction on K-uptake
(Pot Culture Studies)



Effects of Fe-K interaction on Fe-uptake (Pot culture studies)



Effects of K application on leaf bronzing and yield of rice grown on iron toxic soil

Field Trials, Av. of 3 years, pH 4.9, DTPA-Fe 396 mg kg-1

	Leaf bronzing (1-9 scale)		Grain yield (q ha^{-1})		Straw yield (q ha^{-1})	
Levels of K_2O(kg ha^{-1}	Jaya Suscept-ible	Mahsuri Tolerant	Jaya Suscept-ible	Mahsuri Tolerant	Jaya	Mahsuri
0	8	3	10.3	18.2	12.5	25.0
40	7	2	13.8	22.1	16.9	27.7
80	5	2	19.4	22.7	22.9	33.6
120	5	1	22.1	26.8	28.8	35.7
160	3	1	24.4	28.8	31.7	37.4
Mean			18.0	23.7	22.6	31.9

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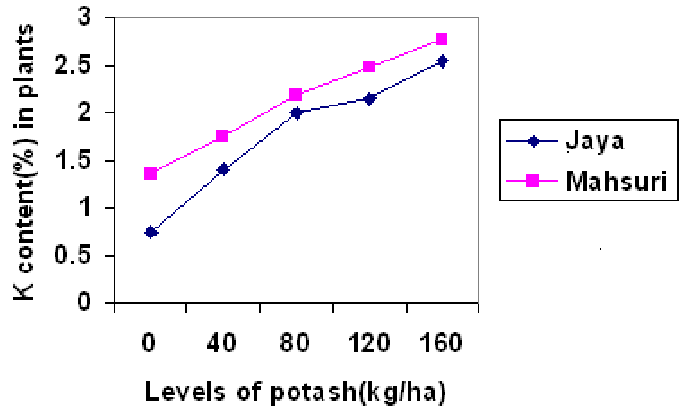
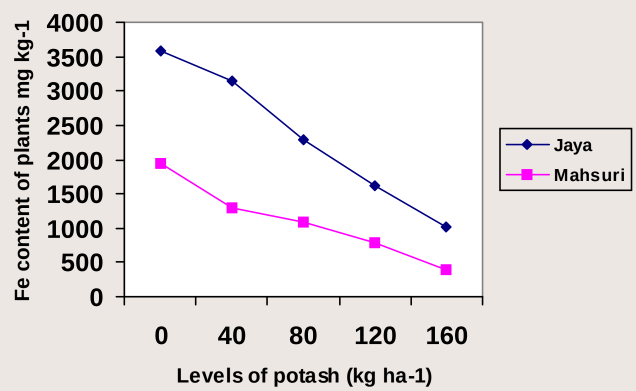
K-content (%) of plants at MT stage for different levels of K

(**Field Trial, pH 4.9, DTPA Fe 396 mg kg^{-1}**)



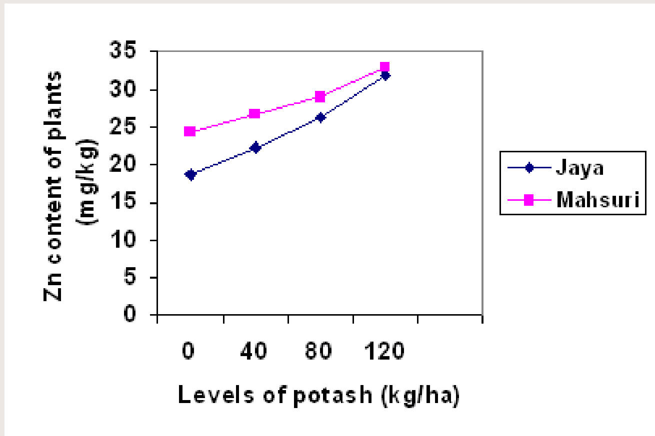
Fe content of plants at MT stage for different levels of potash

(**Field Trial, pH 4.9, DTPA Fe 396 mg kg^{-1}**)



Zn content of plants at MT stage for different levels of potash

(**Field Trial, pH 4.9, DTPA Fe 396 mg kg^{-1}**)



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Need for application of higher doses of K to soils of Orissa

- **Soils of Orissa have a huge negative K-balance of –242.87 thousand tonnes (-30 kg ha)**
- **The deficit is currently met from K-bearing minerals (Mica, orthoclase, microcline etc.) present in the soil. (Pl. see the article of Dr. Jena in the Souvenir)**
- **In LTF-Experiments laid out in 1972-73, responded to K-application in 1982-83.**
- **Application of K at a higher dose (60-80kg ha^{-1})to the main crop rice is essential not only to prevent K-mining,but to alleviate latent iron toxicity of soils. (Rice crop removes 62% of K from the soil.**

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Mechanism of ameliorating effects of K on Fe-toxicity

- Water logged rice roots excrete O_2 to the rhizosphere from aerenchyma tissues, which constitute 40-50% of their cross sectional area (Evans, 2003).
- Application of K in higher doses increases root oxidising power of rice, which results in oxidation of Fe^{++} to Fe^{+++} and exclusion of this ion from uptake.
- This is evident from increase in intensity of iron oxide coating on rice roots at higher levels of K application.
- Results of pot culture and field experiments showed that an increase in K application increased K and Zn content of plants and reduced Fe content.

Mechanism of ameliorating effects of K on Fe-toxicity

- **Lowering of Fe content by K reduces oxidative injury, which is caused by oxidation of Fe^{++} to Fe^{+++} in the apoplast leading to auto-oxidation, Fenton reaction and formation of free radicals such as $O_2^{\bullet-}$ and $HO^{\bullet-}$ resulting in oxidative loss of defense enzymes, catalase, superoxide dismutase etc.**
- **According to Li (2006) K protects super oxide dismutase activity in plants and mitigates injury caused by free radicals of active oxygen.**
- **Potassium increases proline content of leaves and suppresses malondialdehyde (MDA) content formed by lipid peroxidation.**

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Mechanism of ameliorating effects of K on Fe-toxicity

- **Potassium maintains the balance of internal hormone level of CTK, ABA and ethylene.**
- **It maintains integrity of plasma membrane and thus protects the symplast from possible injury from Fe accumulation in the apoplast.**
- ***Leaf bronzing* is caused by precipitation and deposition of ferric compounds in the apoplast.**

Mechanism of ameliorating effects of K on Fe-toxicity

- **The role of genes of Fe and K transporters in alleviating iron toxicity by K is not known.**
- **Under Fe toxic conditions root border cells tend to protect the root tip after sloughing off from it and forming a mucilage, which binds Fe and prevents it from reaching the root tip.(Xing *et al.* 2008)**
- **TRH1 a member of KT/KUP/HAK family of K-transporter genes encodes a K transporter protein essential for root tip growth.(Rigas *et al. 2001*)**

(Please read the article on K-transporters in the Souvenir)

Contrary views

Mehraban *et al.* (2008)

- **Potassium nutrition could not alleviate effects of iron stress on plant growth.**
- **Iron toxicity induced greater oxidative stress in rice plants and supplemental potassium was ineffective in preventing iron accumulation in shoots and consequently did not ameliorate plant growth under iron toxic levels.**

Thank you