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.

The Extant of the Problem

- **6.73 million ha of land is affected by salinity and alkalinity problem in India**
- **25 % of ground water used for irrigation is either saline or brackish**
- **11.7 million ha is likely to be affected by salinity and alkalinity in India by 2025**
- **At global level, 810 million ha is affected by sodicity (434 million ha) and salinity (376 million ha)**
- **10 million ha of land are lost because of salinity caused by irrigation each year (George E. Brown Jr. Salinity Laboratory, 2006)**

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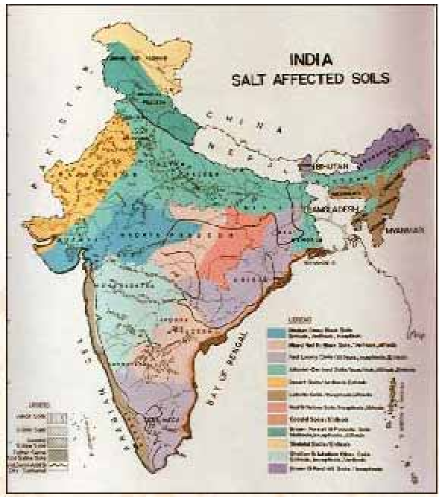
Resource Inventories on Salt Affected Soils in India

- Salt affected Area 6.73 million ha
- Sodic soils
  3.77 million ha
- Saline soils
  2.96 million ha



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Coastal major salt affected soils

Coastal major salt affected soils

- **Saline soil**: Soils having pH <8.5, ECe>4 dS/m, ESP<15, Preponderance of Chlorides & sulpha -tes of sodium, Calcium & magnesium
- **Sodic soil**: Soils having pH >8.5, ESP≥15, ECe<4 dS/m, Preponderance of Carbonate and bicarbonates of sodium
- **Acid sulphate soil**: Present in coastal swamps and mangro -ve forests, caused by supply of sulphate salts from sea. Rich in OM and fatty acids. Results in production of acid from oxidation of Pyrites, pH<4.

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What are the options ?

1. Change of the environment (soils) to suit existing crops

a. Use of chemical amendments (Gypsum, pyrites, Sulphuric acid etc.

b. Leaching of salts out of root zone

2. Change the crops to suit the soils

3. Grow halophytes

What are the various components of Salt Stress?

- **Reduced water potential**
- **Specific ion stress and toxicity**
- **Ion imbalance or nutrient deficiency**
- **High pH**
- **Excess of exchangeable sodium (Na^+) on exchange complex**
- **Poor soil physical conditions including reduced infiltration, soil compactness and anaerobiosis**

• Salt affected soils are problems for agriculture as almost all the crops show decline in growth and yield to various extent depending upon the level of stress and the potential of the crops or their cultivars to tolerate these stresses.

• In spite of poor salt tolerance of our crops, there are considerable variations among the different crops and their cultivars to tolerate salt stress.

• Most salt-affected soils are deficient in N and Zn and are medium to high in K.

• Each unit increase in pH decreases availability of Zn by 100 fold (Lindsay, 1972).

• Salt-affected soils, the concentrations of boron, lithium, fluorine, selenium and molybdenum could be toxic. B, Li, and Fl are phyto-toxic, whereas Se and Mo may not adversely affect plant growth but the crops, particularly forages growing in salt affected soils with high Se and Mo, may contain excessive concentration of these elements causing health hazard to animals.

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Effect of 12 years of rice - wheat and 8 years of pearmillet - wheat cropping sequence and fertilizers use on available P status and crop yield in a sodic soil

Treatment Rice/ millet Wheat	Grain yield (Mg ha^{-1})				Av. P (kg ha^{-1})	
	Rice 1974 - 1985 Mean	Wheat 1974 - 75 1985 - 86 Mean	Millet* Mean 1986-93	Wheat Mean 1986-94	After 1985- 86 Wheat	After 1993 - 94 Wheat
Control	3.17	1.04	0.75	1.10	17.9	9.6
N N	5.33	4.53	1.71	3.48	8.7	4.0
NP NP	6.84	4.89	1.95	4.78	67.1	60.0
NP N	6.79	4.87	1.93	4.49	45.2	14.6
N NP	6.71	4.93	1.94	4.66	45.9	15.6
NPK NPK	6.96	4.83	2.11	4.90	67.4	56.6
NPK N	6.80	4.62	2.07	4.58	44.7	15.0
N NPK	6.59	4.70	2.01	4.71	46.5	14.8
LSD (p=0.05)	0.52	0.41	0.38	0.54	8.9	5.9

* Average of six crops. Pearl millet (bajra) crop during 1988 and 1990 was completely damaged due to heavy floods.

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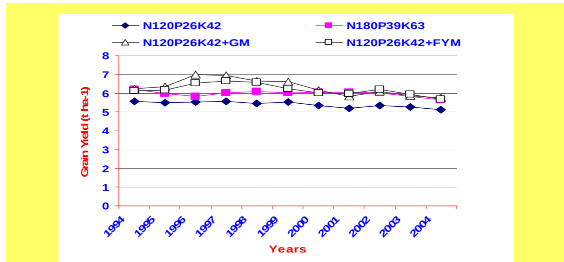
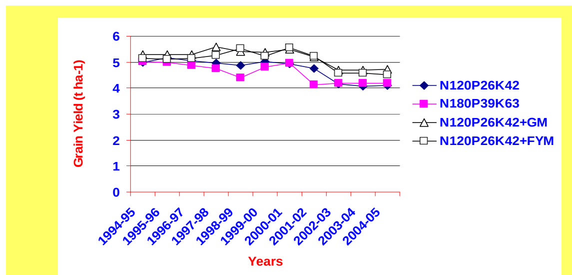
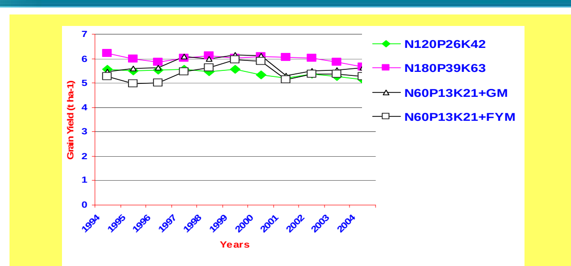
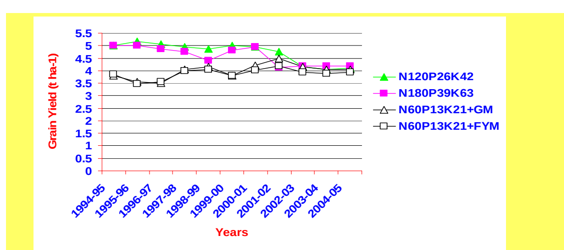
Trend of rice and wheat yield in different treatments





Trend of rice and wheat yield in different treatments





❖ To get the maximum advantage from the applied fertilizer-N, it must be given in right quantity, at the right time and place, from the right source, and in the right combination.

❖ Nitrogen application should synchronize with the growth stage at which plants have the maximum requirement for this nutrient. Rice and wheat plants use nitrogen most efficiently when it is applied at the maximum tillering stage. Rice plant uses N around the panicle initiation/jointing stage also.

❖ Therefore, split application of N for wheat (1/2 at sowing, remaining 1/2 N in two splits at tillering (21 days) and 42 days after sowing and for rice (half at transplanting + 1/4 at tillering + 1/4 at panicle initiation) resulted maximum efficiency (Dargan and Gaul, 1974). Another field experiments have shown that maximum yields of rice and wheat were obtained when N was applied in 3 equal splits, as basal and at 3 and 6 weeks after transplanting/sowing

Ammonia losses from INM in rice field

Treatments	Amount of N lost during application			Total-N lost	% Urea-N lost
	Basal	1st Top	2nd Top		
Control	1.23	-	-	1.23	-
N_{120}	8.49	8.21	6.76	23.46	19.55
$N_{120}P_{26}$	8.28	7.35	6.70	22.33	18.61
$N_{120}P_{26}K_{42}$	8.14	7.24	6.65	21.75	18.13
$N_{120}P_{26}K_{42}$ + GM	5.82	5.20	5.06	16.75	13.40
$N_{120}P_{26}K_{42}$ + FYM	6.73	5.74	5.28	17.75	17.79
$N_{180}P_{39}K_{63}$	12.12	10.60	9.48	32.20	17.89
CD at P=0.05	0.51	0.91	1.19	-	-

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Phosphorus:

❖ Phosphorus is constituent of a large number of macromolecules like phospholipids, nucleic acids, phosphoproteins, dinucleotide and adenosine triphophate etc. and required for processes including the storage and transfer of energy, photosynthesis, the regulation of some of the enzymes and transport of carbohydrates.

❖ The plant roots largely absorb it as dihydrogen orthophosphate ion ($H_2PO_4^-$), however, under neutral to alkaline environments, it is also taken up as monohydrogen orthophosphate (HPO_4^{2-}) ion.

❖ The high amounts of Na_2CO_3 and Na_2HCO_3 react with native insoluble calcium phosphates to form soluble sodium phosphate and hence give a positive correlation between the electrical conductivity and their soluble P status.

❖ Due to high pH and the presence of soluble carbonates and bicarbonates, sodium phosphates are formed in these soils, which are water soluble. Sodic soils are reported to contain high amount of soluble phosphorus.

Response of rice to increased level of Phosphorus in sodic soil

Growth and yield	Level of P Fertilization (kg/ha)			CD (0.01)
	P0	P40	P 80	
Shoot D. Wt. (g/pot)	36.0	44.8	46.8	3.8
Fert.Till./Plant	5.2	8.0	8.5	1.6
Filled grain/Panicle	60.7	81.6	85.8	5.5
K (% D.Wt.)	1.08	1.28	1.35	0.11
P (% D. Wt.)	0.194	0.225	0.239	0.016

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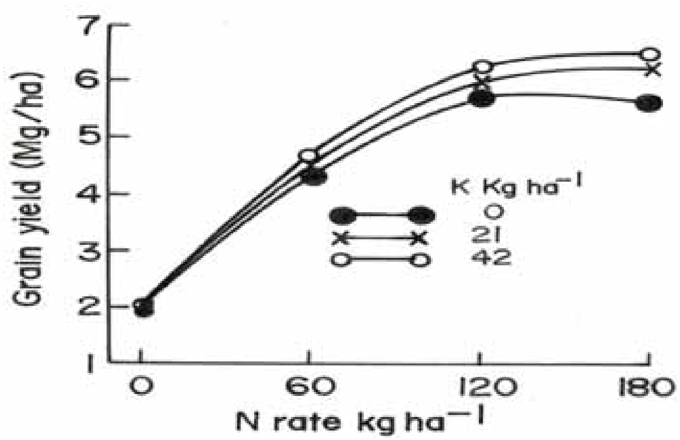

Effect of N and K on yield of wheat in saline soil.

Extent of Zn deficiency Problem

- Zn is a heavy metal and essential for both plants and animals
- About **48.6%** of soil samples tested in co-ordinated project were found low/deficient in Zn

Nearly **50%** of the cereal grown areas in the **world** have soils with low/deficient plant available Zn

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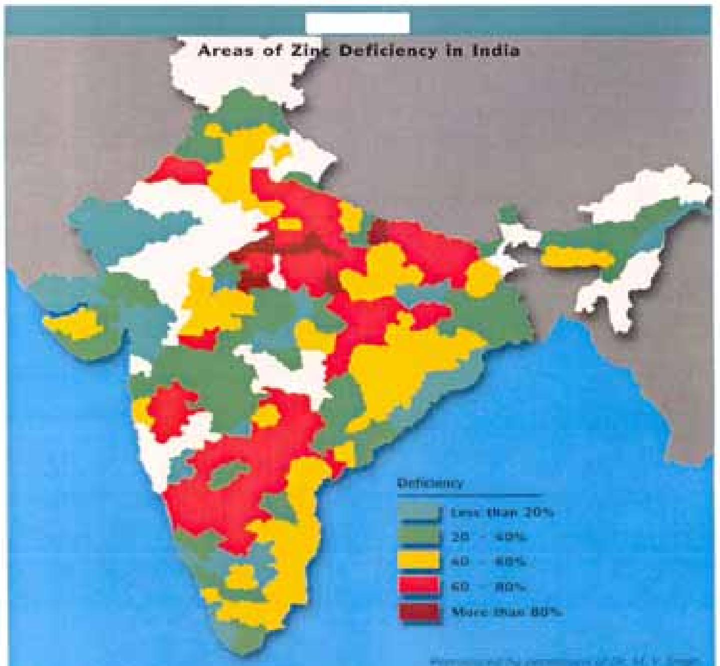
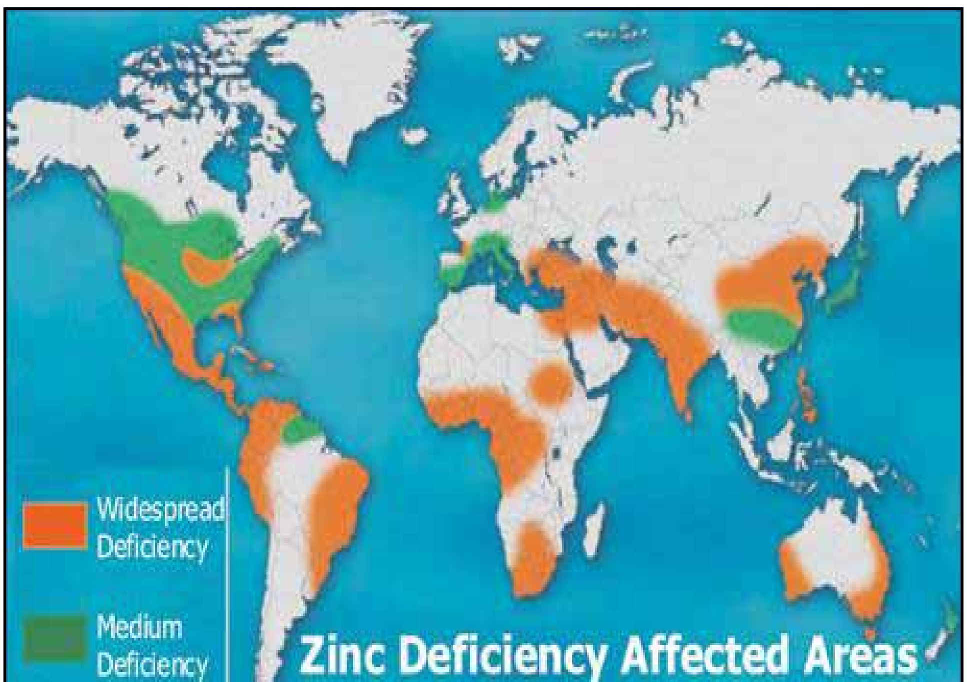

Areas of Zinc Deficiency in India
Deficiency
Less than 20%
20 - 40%
40 - 60%
60 - 80%
More than 80%


Widespread Deficiency
Medium Deficiency
Zinc Deficiency Affected Areas

Critical concentrations of Zinc from leaf analysis of crops

Crops	Severity of deficiency	Critical concentration (mg Zn/kg dry matter)
Wheat	Acute	< 8 ppm (whole plant)
	Moderate	8-12 (do)
	Latent	12-20 (do)
	No response to Zn	>20 (do)
Rice	Deficiency	<10-15 (do)
Maize	Deficiency	< 20-22 (do)
Sorghum	Deficiency	8 (do)

Typical symptoms of interveinal chlorosis in zinc deficient rice plants

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Response of CSR 10 (sodicity tolerant rice cultivar) to added Zinc

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Comparative response of rice cultivars to increased level of DTPA Zinc in sodic soil

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Effect of iron and zinc application on yield concentration and uptake of Zn by rice

Treatment [a]	Yield (t ha^{-1}) Grain	Straw	Zn concentration (mg kg^{-1}) Leaves[b]	Grain	Straw	Total Zn uptake (g ha^{-1}) Grain +Straw
Fe_0Zn_0	4.9	7.14	9.5	12.7	15.1	167.2
$Fe_{55}Zn_0$	4.8	7.00	9.0	11.0	14.0	151.8
$Fe_{110}Zn_0$	4.4	6.62	8.6	9.0	12.4	122.3
Fe_0Zn_{11}	5.5	7.85	14.5	14.2	19.2	29.7
$Fe_{55}Zn_{11}$	5.6	7.89	13.8	13.4	19.0	226.1
$Fe_{110}Zn_{11}$	6.0	8.32	12.8	12.5	17.2	218.7
LSD at p=0.05						
Fe	NS	NS	0.6	0.7	0.6	-
Zn	0.21	0.42	1.1	1.2	1.2	-
FexZn	0.37	0.54	NS	NS	NS	-

Response of rice to increased levels sodicity

Growth and yield	Sodicity levels 8.0	9.3	9.9	CD (0.01)
Shoot D. Wt. (g/pot)	55.2	45.9	30.8	3.4
Fert.Till./Plant	8.7	8.0	5.8	1.4
Filled grain/Panicle	94.9	81.3	60.9	4.9
K (% D.Wt.)	1.84	1.28	0.83	0.09
P (% D. Wt.)	0.196	0.216	0.239	0.014

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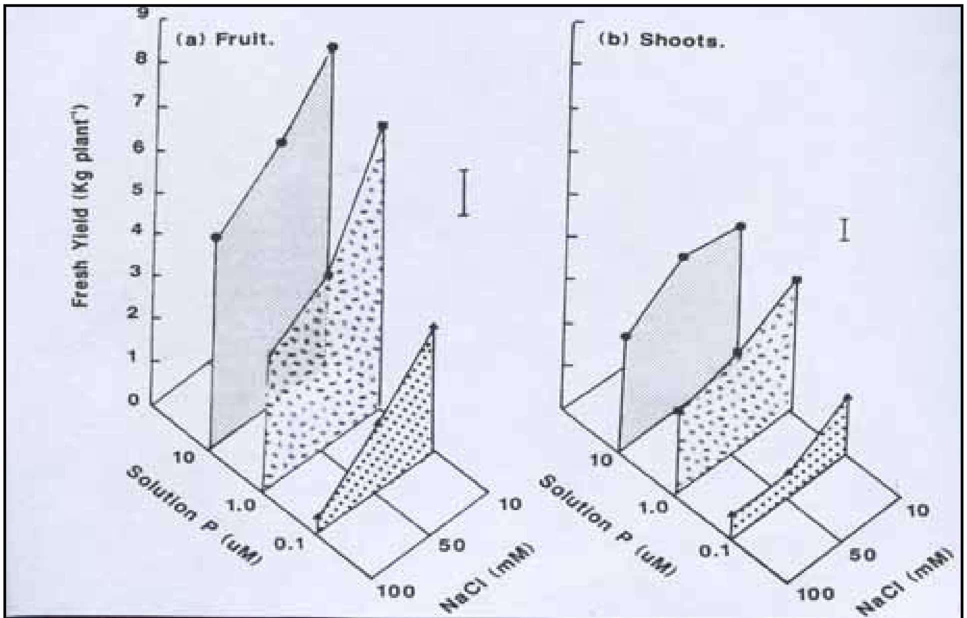

Effect of NaCl on fresh yield of fruit and shoots of tomato plants grown at different P levels in N.S. (CD 0.05)

Every time wheat is irrigated
in many areas it is likely also waterlogged
(waterlogging = redox ≤350 mV; anoxia)

Irrigation in **NEUTRAL** soils (pH 7.8)= 3.5 d waterlogging*

6 irrigations = <u>21d waterlogging/season</u>

Irrigation in **SODIC** soils (pH 9.2-9.6)= 8-10d waterlogging*

6 irrigations = <u>48-60d waterlogging/season</u>

<u>Note</u>:

Every day roots are waterlogged, root growth STOPS.

Roots can die after only 24 h waterlogging (anoxia).

Extrapolation during entire season needs confirmation

Conclusions:
Waterlogging is a major constraint to crops production, particularly in sodic soils.
Note: WL is a likely result of rice-wheat farming systems and rice soil management.

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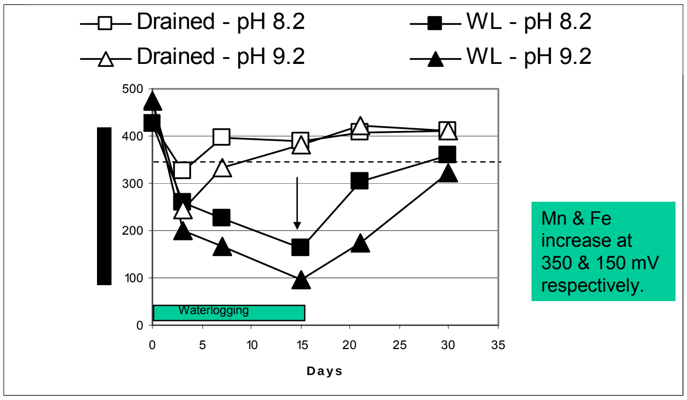
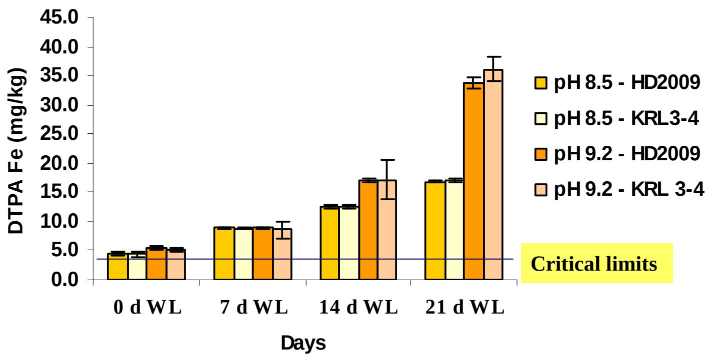
Arrow indicates timing of surface water removal; dashed line anoxia.



Conclusions:

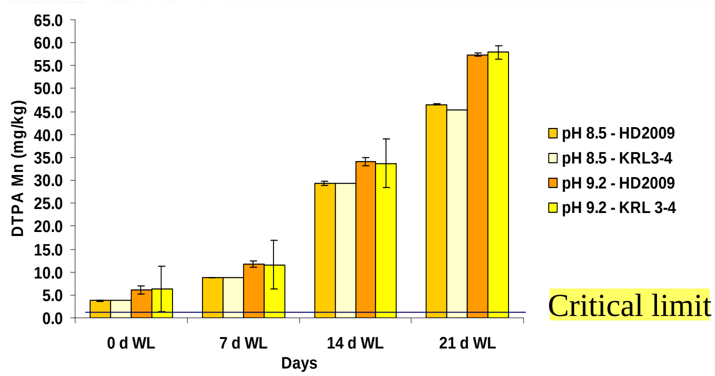
1) With in 2-3d, WL reduces soil redox potentials to <350 mV (anoxia).
2) After WL ends, soils take at least 15-20 d to recover / become re-aerated.
3) Both Mn and Fe are predicted to significantly increase in these soils.
4) WL also occurs for up to 8d in "drained" soils due to irrigation.
5) In farmers' fields recovery may take up to 30 d (Preliminary Report, 2006)

Fe concentrations (ppm) of soil and different days of waterlogging in sodic soil



Soils: WL 6 fold increased DTPA Fe conc. than drained condition but 10 fold increased for critical limits of Fe (4.5 mg/kg) (Yaduvanshi et al.).
<u>Plants:</u> Large increases in Fe occur in <u>shoots of plants</u> exposed to waterlogging (Sharma et al.).
<u>Impact</u>: Microelement toxicities may result in the reduced growth, and lack of recovery ability in some varieties

Mn concentrations (ppm) of soil and different days of waterlogging in sodic soil



Soils: WL caused 12-15 time higher than drained conditions but these conc. were 60 times higher than critical concentrations (DTPA Mn 1.0 mg/kg)

Plants: Large increases in Mn occur in shoots of plants exposed to waterlogging

Impact: Microelement toxicities may result in the reduced growth, and lack of recovery ability in some varieties

Conclusion

- The activities of nutrient elements are altered because of excess of potentially toxic ions in salt affected soils
- pH influences solubility and availability of nutrients.
- Nitrogen is the most limiting nutrient in these soils and 25% more N should be applied.
- Olsen's P in these soils particularly under sodicity is very high. After 3-5 years, 11 kg P ha^{-1} to be given to only rice for another 5-10 years followed by 22 kg P ha^{-1} to both rice and wheat crop.
- Addition of P (within a certain range) in several studies not only helped plants in terms of growth and yield, but also improved the tissue tolerance

Contd.

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- Those crops especially the horticulture, which are highly sensitive to Cl toxicity are likely to be benefited by adding more N as NO_3 to offset the effects of Cl on its uptake.
- Excess of Na not only reduces Ca availability, its transport and mobility to growing regions of the plants, but also impairs the integrity of cell membrane leading to uncontrolled influx and efflux of several elements.
- Alkali soils contain low amounts of DTPA extractable Zn.
- The efficiency of applied Zn fertilizer is much less and the crops especially rice suffers.

Thanks for your Kind Attention

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