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*Shaping Lives...
Empowering Communities...*

Management of Waterlogged Soil and Their Impact in Agriculture

Dr. Arunabha Pal

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- ✿ **Conclusions**
- ✿ **Path ahead**



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What is waterlogged soil ?

- Waterlogged soils are soils that are **saturated** with water for a sufficiently long time annually to give the soil the distinctive **gley horizons** resulting from oxidation-reduction processes:
 - a **partially oxidized** A horizon high in organic matter,
 - a **mottled zone** in which oxidation and reduction alternate, and
 - a **permanently reduced** zone which is bluish green .

- Robinson (1949)

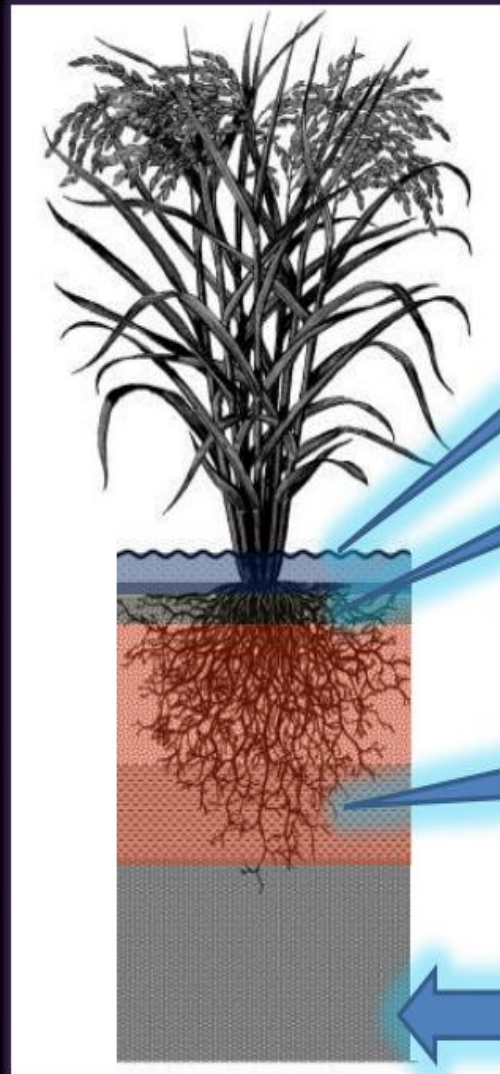




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Submerged profile



Free surface
water

Partially
oxidized layer
 $Eh > 400 \text{ mV}$

Permanently reduced
and mottled layer
 $Eh < 400 \text{ mV}$

Plough sole
sub soil

Das (2002)



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Types of waterlogged soils

- ❖ **Riverine flood waterlogged soil**
- ❖ **Oceanic flood waterlogged soil**
- ❖ **Seasonal waterlogged soil**
- ❖ **Perennial waterlogged soil**
- ❖ **Sub-soil waterlogging**



Agropedia (2010)

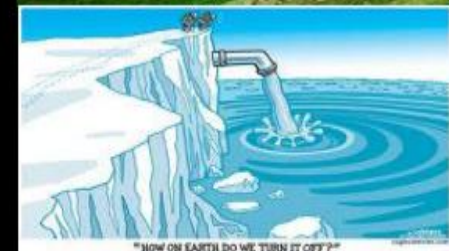


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Factors affecting formation of waterlogged soil

- ❖ **Climatological : Rainfall and Flood water**
- ❖ **Irrigation : Uncontrolled, Unwanted**
- ❖ **Drainage : Poor drainage**
- ❖ **Topography : Depressed land**
- ❖ **Land shape : Saucer shaped land
become waterlogged**
- ❖ **Height of ground water table:
Higher ground water table**



Agropedia (2010)

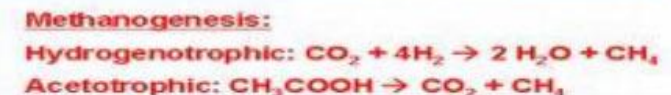
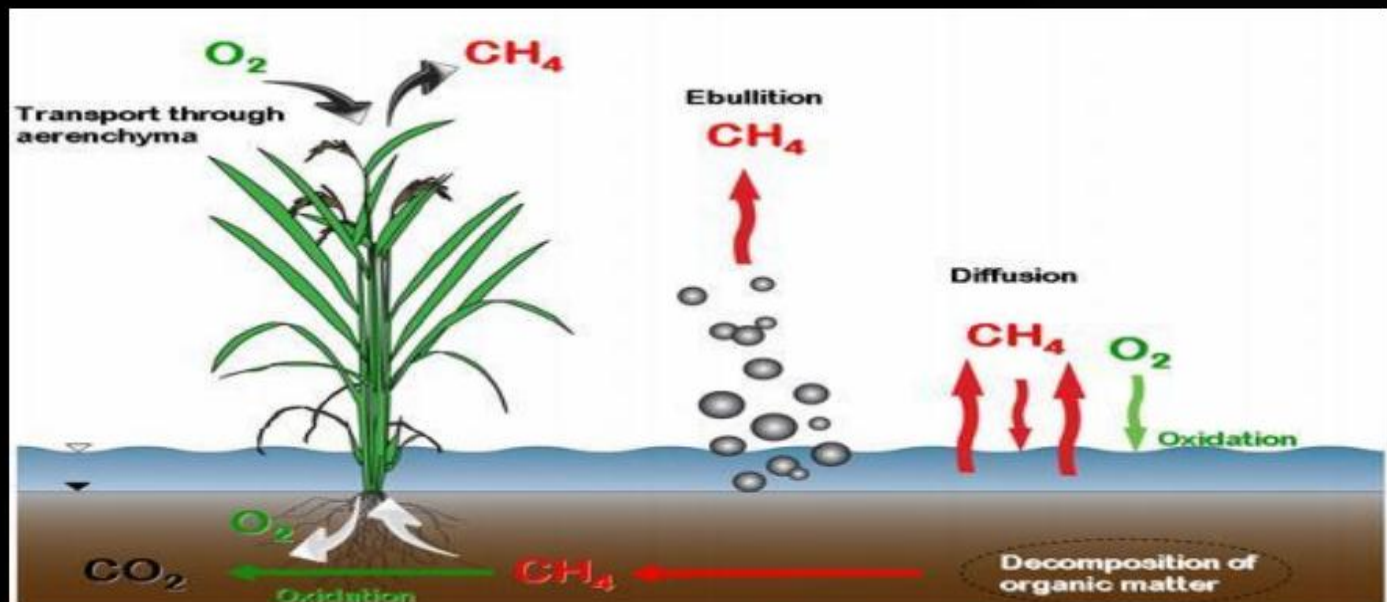


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Characteristics exhibits in waterlogged soil

- **Greater amount of soil solution**
- **Reduced oxygen level**
- **Reduced aerobic microbial activity**
- **An altered chemical status of soil**





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Coverage

- ❖ **Submerged soils covers 5% to 7% of earth land surface.**
- ❖ **The total global waterlogged soil is approx. 700 to 1000 Mha .**
- **North America and Russia (34%of total area),**
- **Tropical swamps,(14%)**
- **Tropical floodplains(10%);**
- **Temperate and tropical rice fields (4% & 12%).**



Guy Kirk (2004)



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Present scenario in India

States	Waterlogged soil (ha)
Andhra Pradesh	10654
Arunachal Pradesh	0
Assam	46021
Bihar	188070
Chhattisgarh	521
Goa	0
Gujarat	0
Haryana and Delhi	0
Himachal Pradesh	0
Jammu and Kashmir	0
Jharkhand	3321
Karnataka	0
Kerala	0
Madhya Pradesh	333

Total = 0.99 Mha

States	Waterlogged soil (ha)
Maharashtra	0
Manipur	8517
Meghalaya	1606
Mizoram	0
Nagaland	0
Orissa	242838
Punjab	0
Sikkim	0
Rajasthan	4108
Tamil Nadu	0
Tripura	14721
Uttar Pradesh	131428
Uttaranchal	0
West Bengal	240480

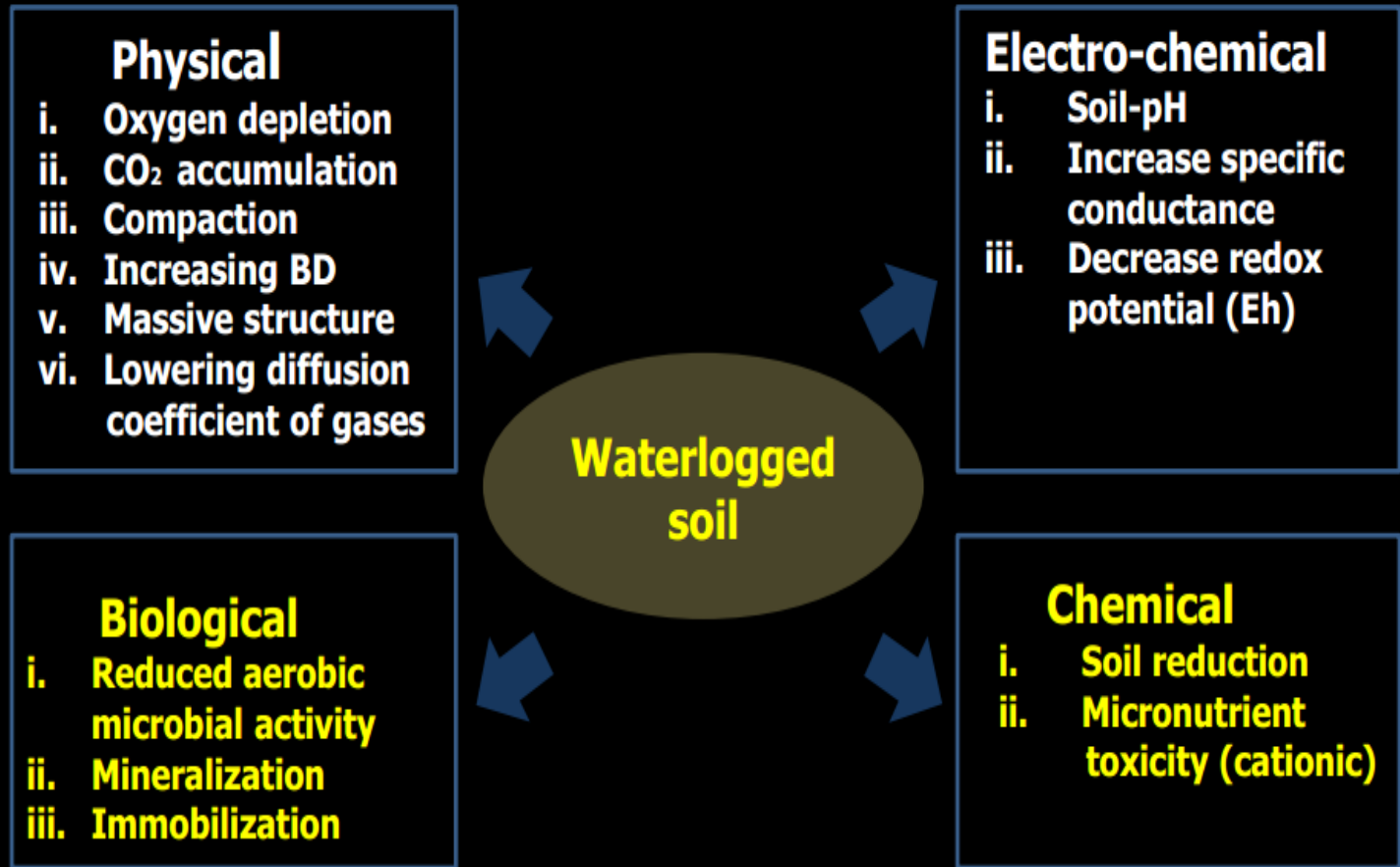
ICAR (2011)



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Properties of waterlogged soil



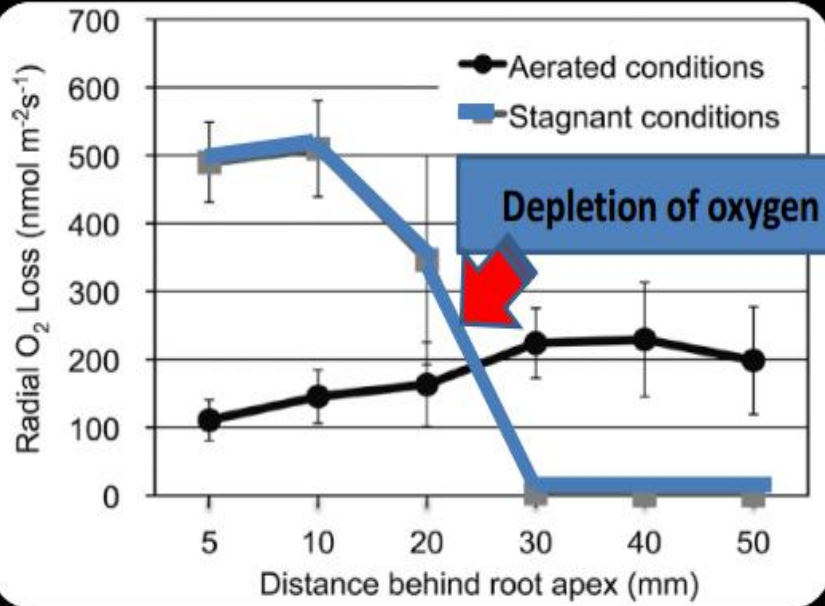


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Physical properties

Increased bulk density, compaction, lesser porosity



Normal soil structure



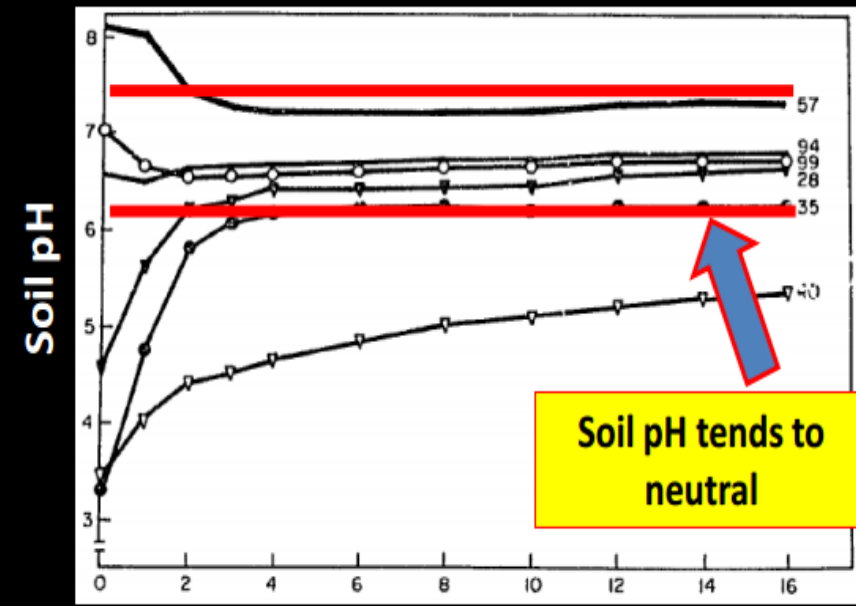
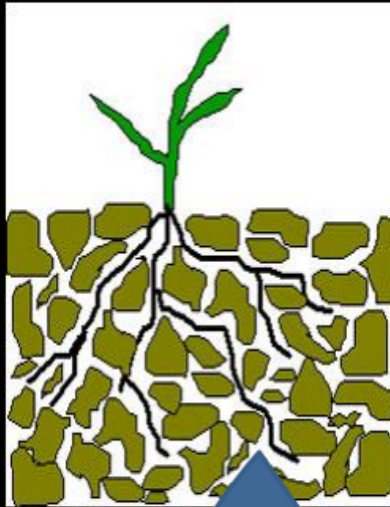
Nishiuchi (2012)



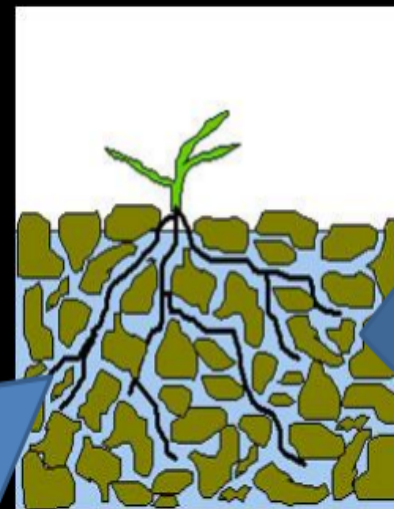
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Soil pH

Normal soil



Waterlogged week



Waterlogged soil

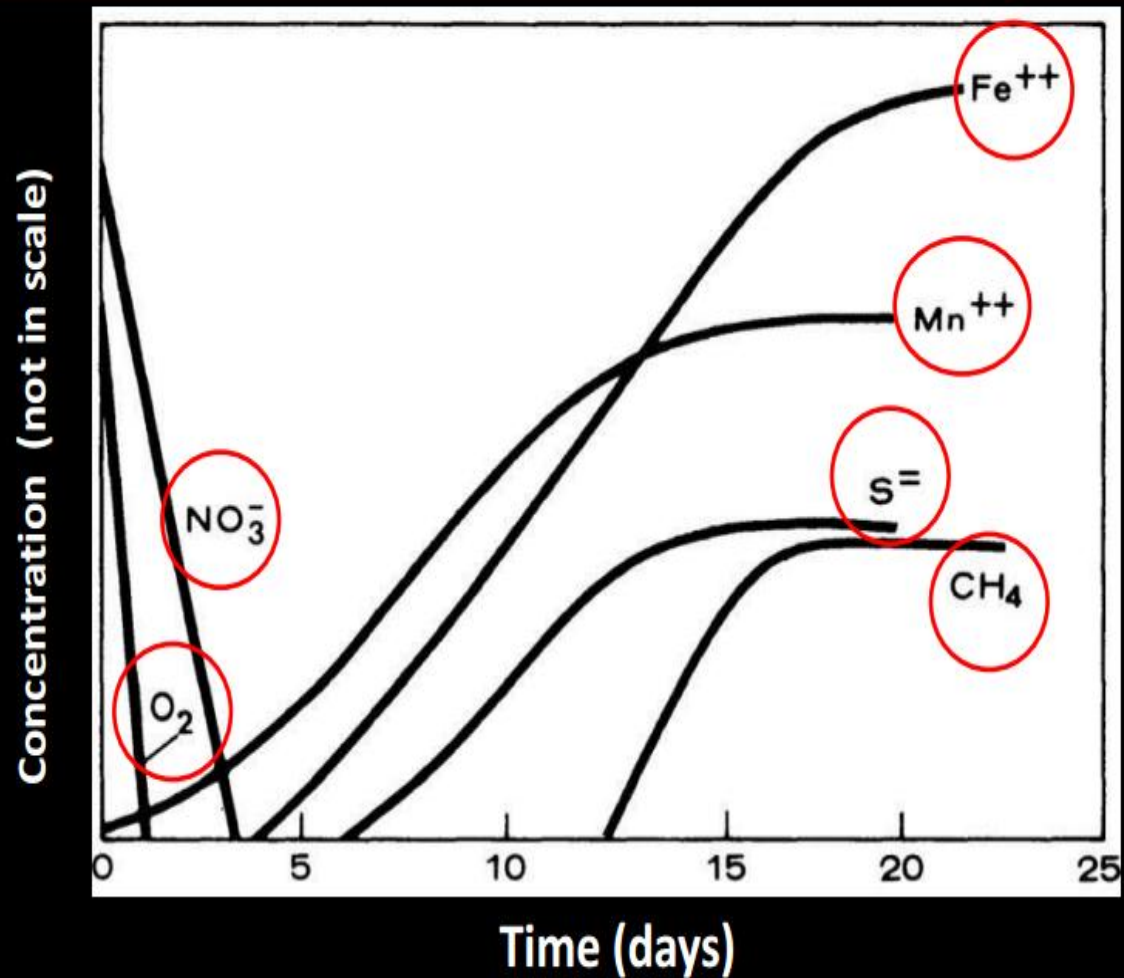
Ponnamperuma (1972)



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Nutrients behavior during waterlogging

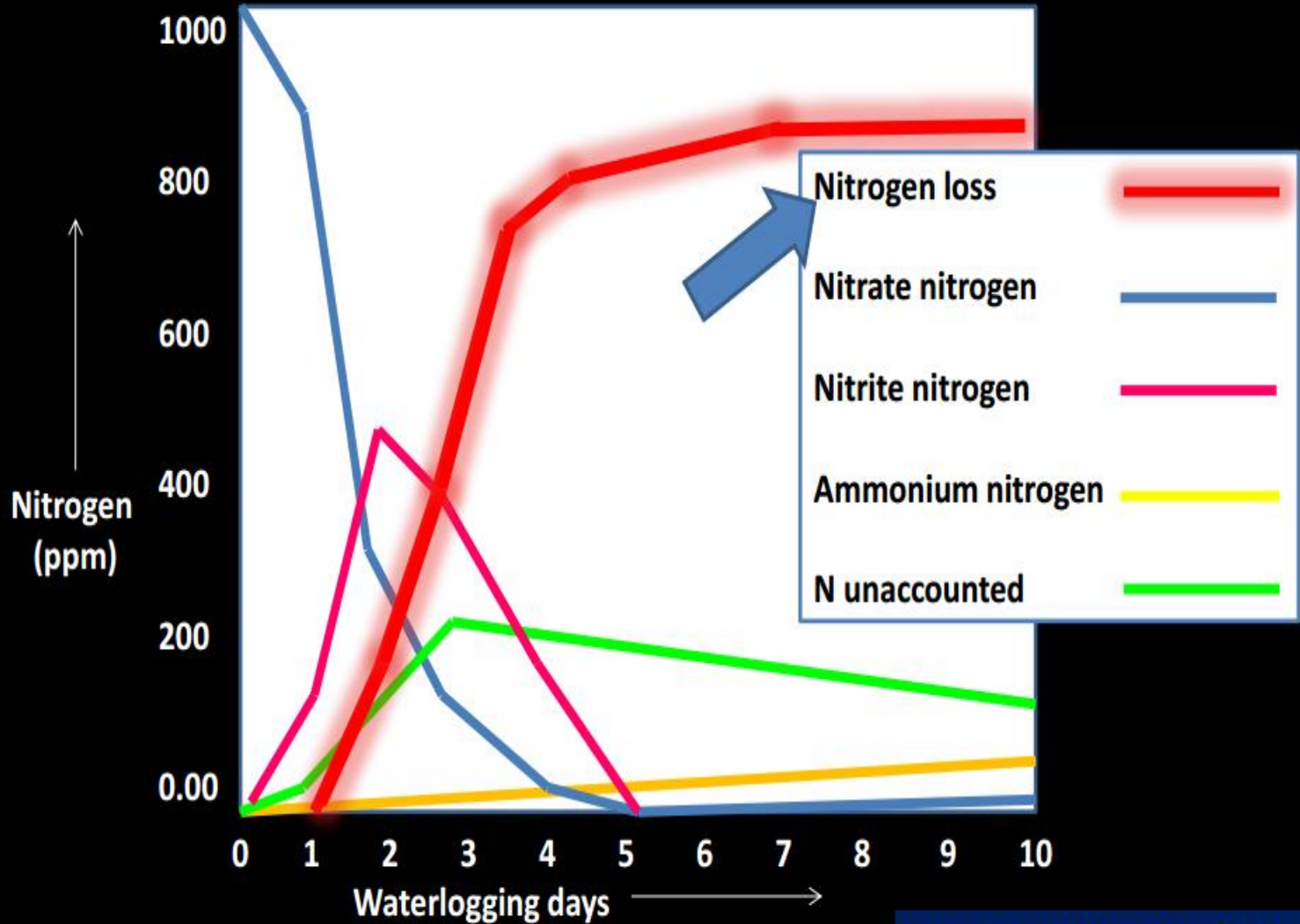




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Nitrogen transformation after waterlogging

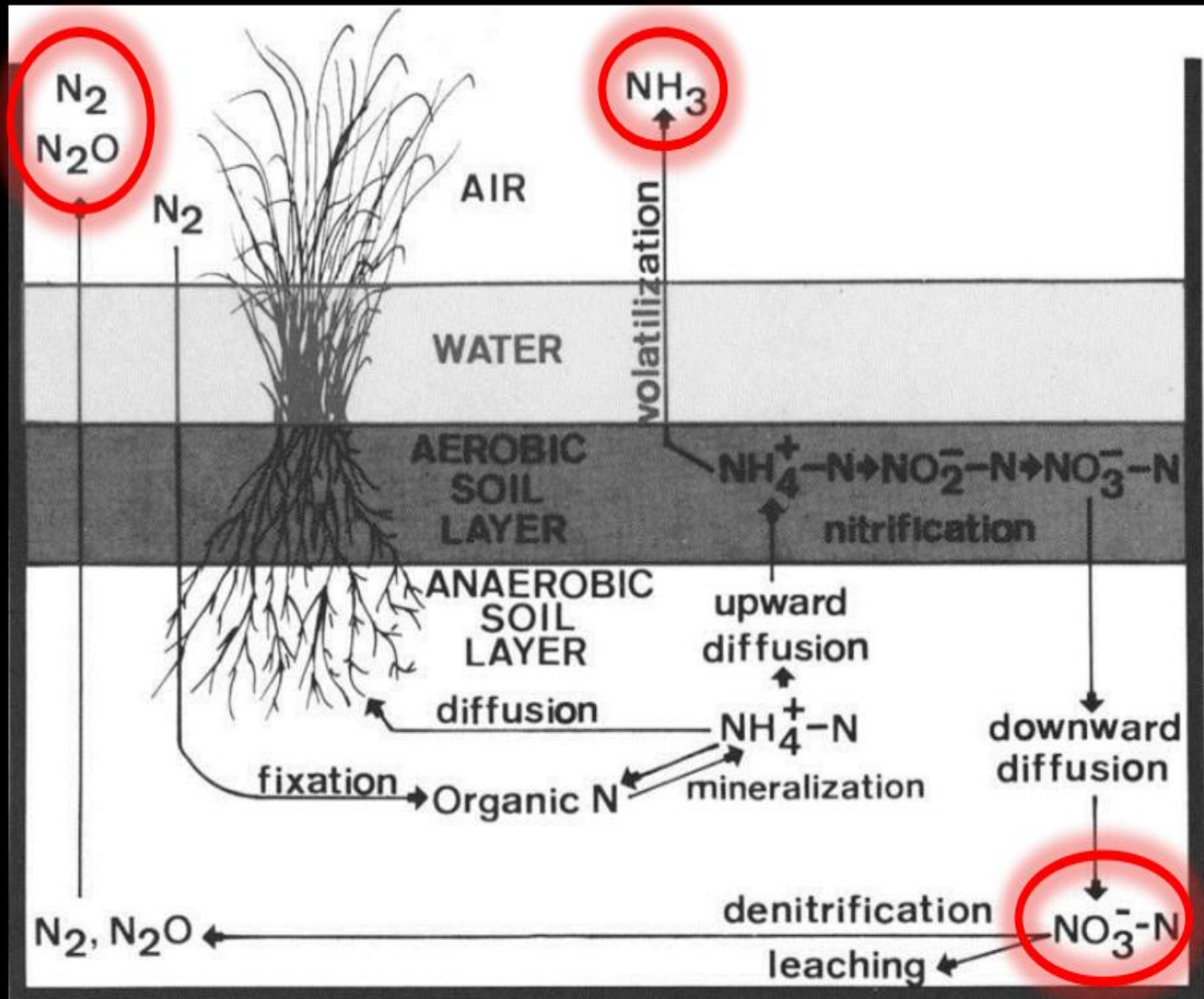


Patric and Mahapatra (1968)



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Nitrogen movement in waterlogged soil

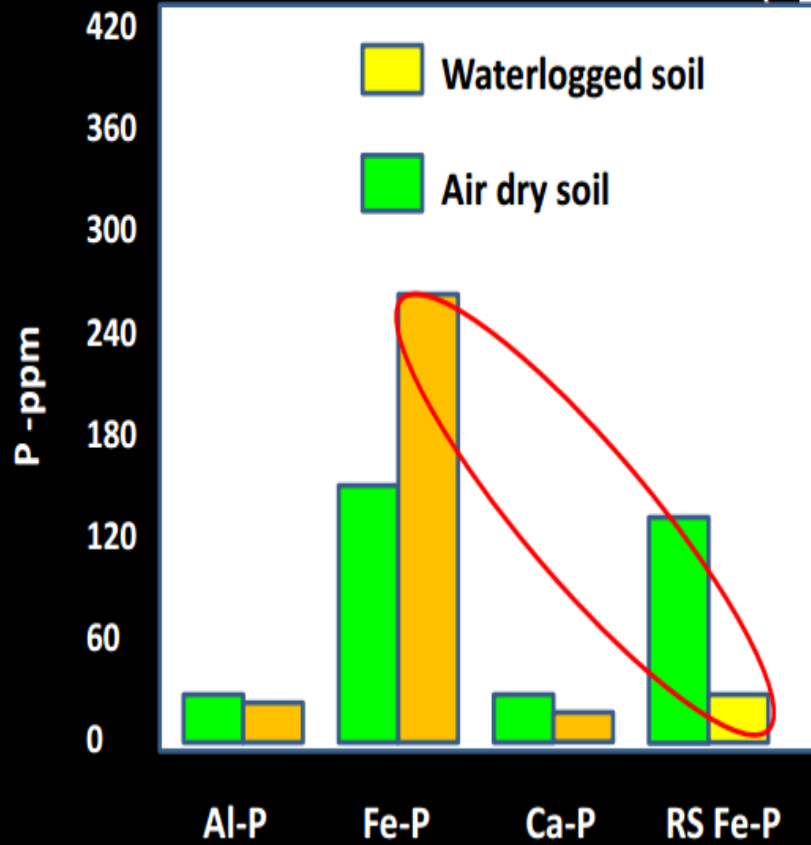




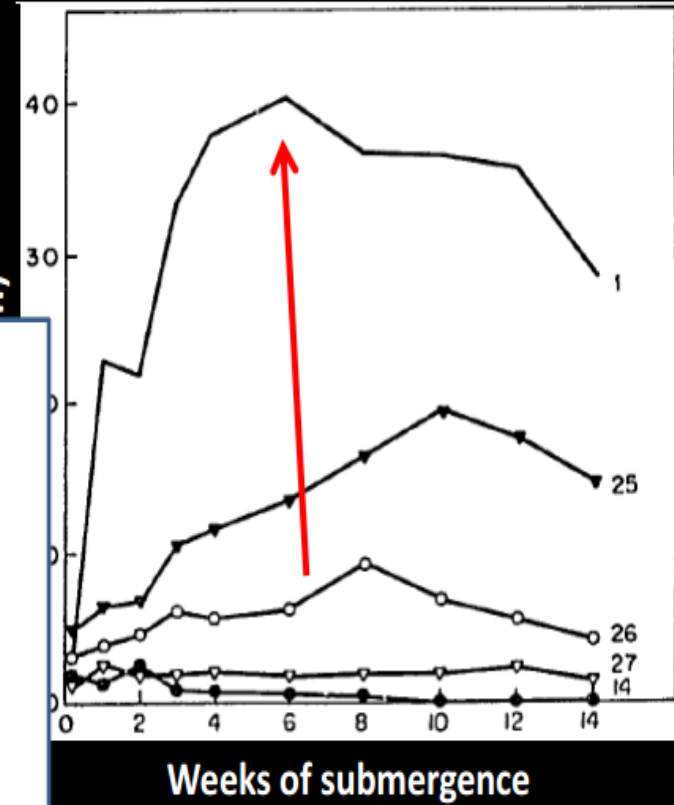
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Transformation of inorganic P in waterlogged soil



Mahapatra (1966)



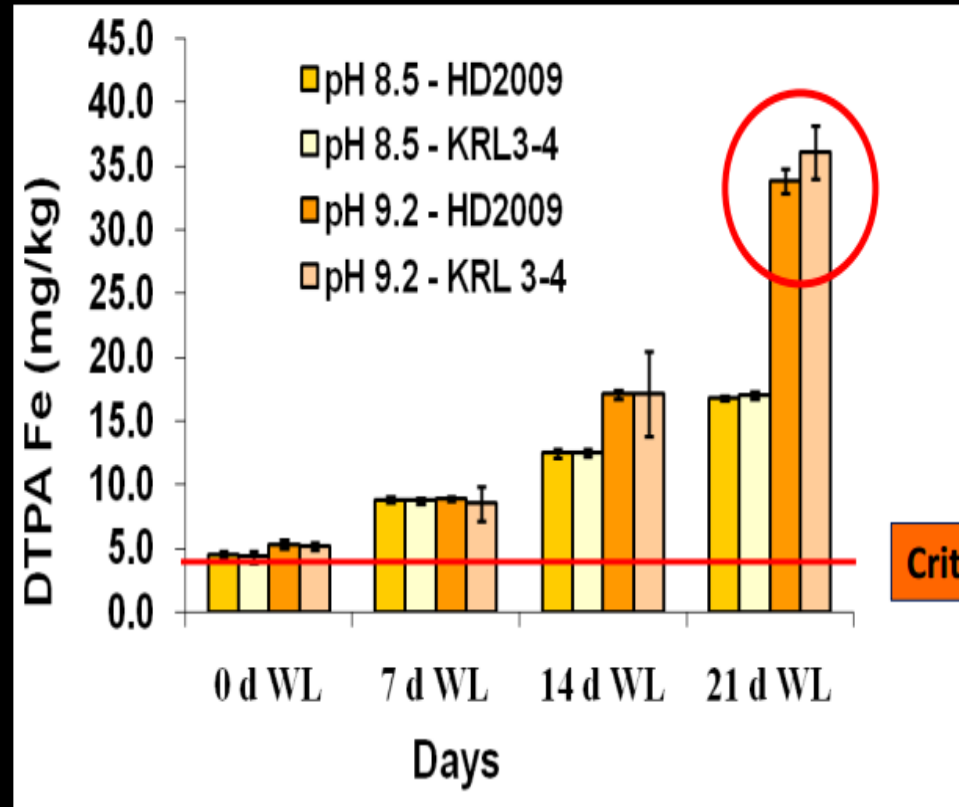
Ponnampereuma (1972)



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Iron toxicity with waterlogging



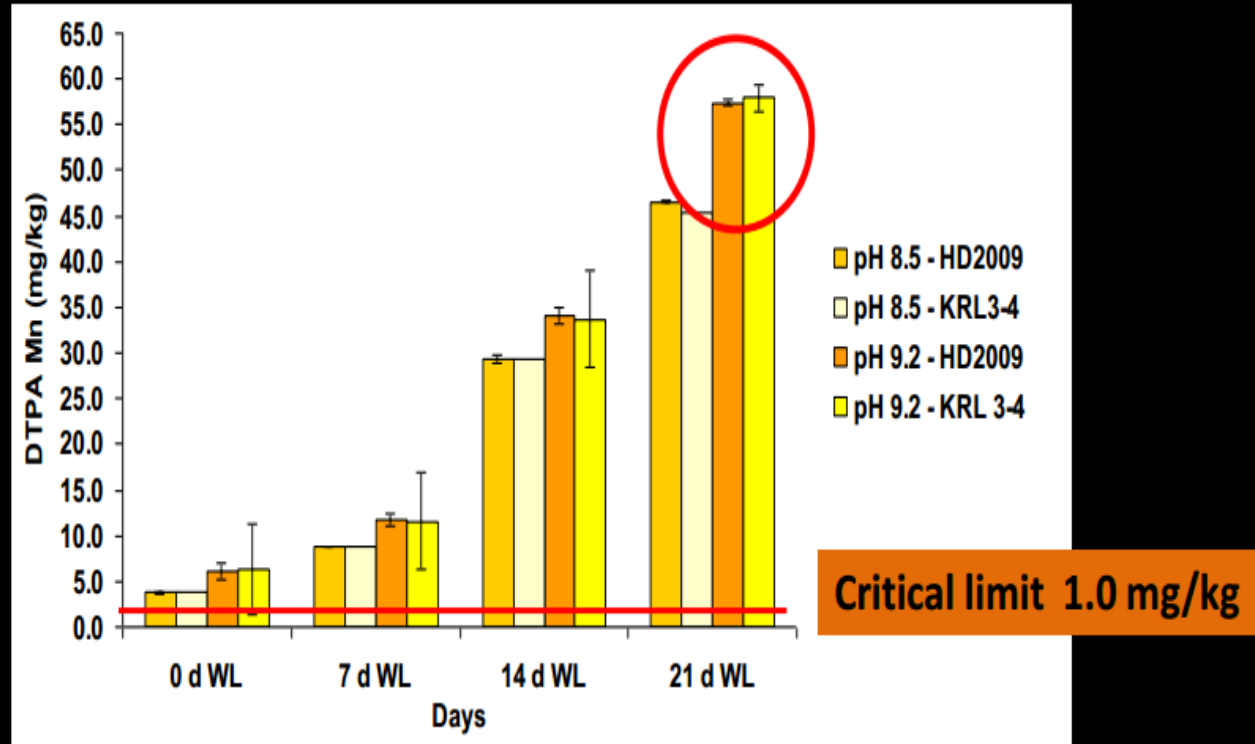
Waterlogging caused a **6 fold** increase in DTPA Fe conc. In both soils at 21 days after waterlogging compared with drained condition



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Manganese toxicity with waterlogging



Waterlogging caused a **12-15 fold** increase in DTPA-Mn in both the soils at 21 days after waterlogging

Yaduvanshi *et al.* (2012)



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Crop yield (t ha^{-1}) and losses (%) under water logging and soil salinity

Crop	Yield (t ha^{-1})		
	Normal lands	Salt affected lands	Waterlogged lands
Paddy	39.9	21.8 (45)	23.0 (42)
Wheat	26.0	15.8 (40)	18.6 (38)
Cotton	16.3	6.1 (63)	3.7 (77)
Sugarcane	636.8	330.2 (48)	247.5 (61)

Joshi (1994)



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Affected crop growth

Spring waterlogging of poorly drained field of peas and injury sustained by leaves of a pea plant after several days waterlogging



Wilting of sunflower during summer waterlogging



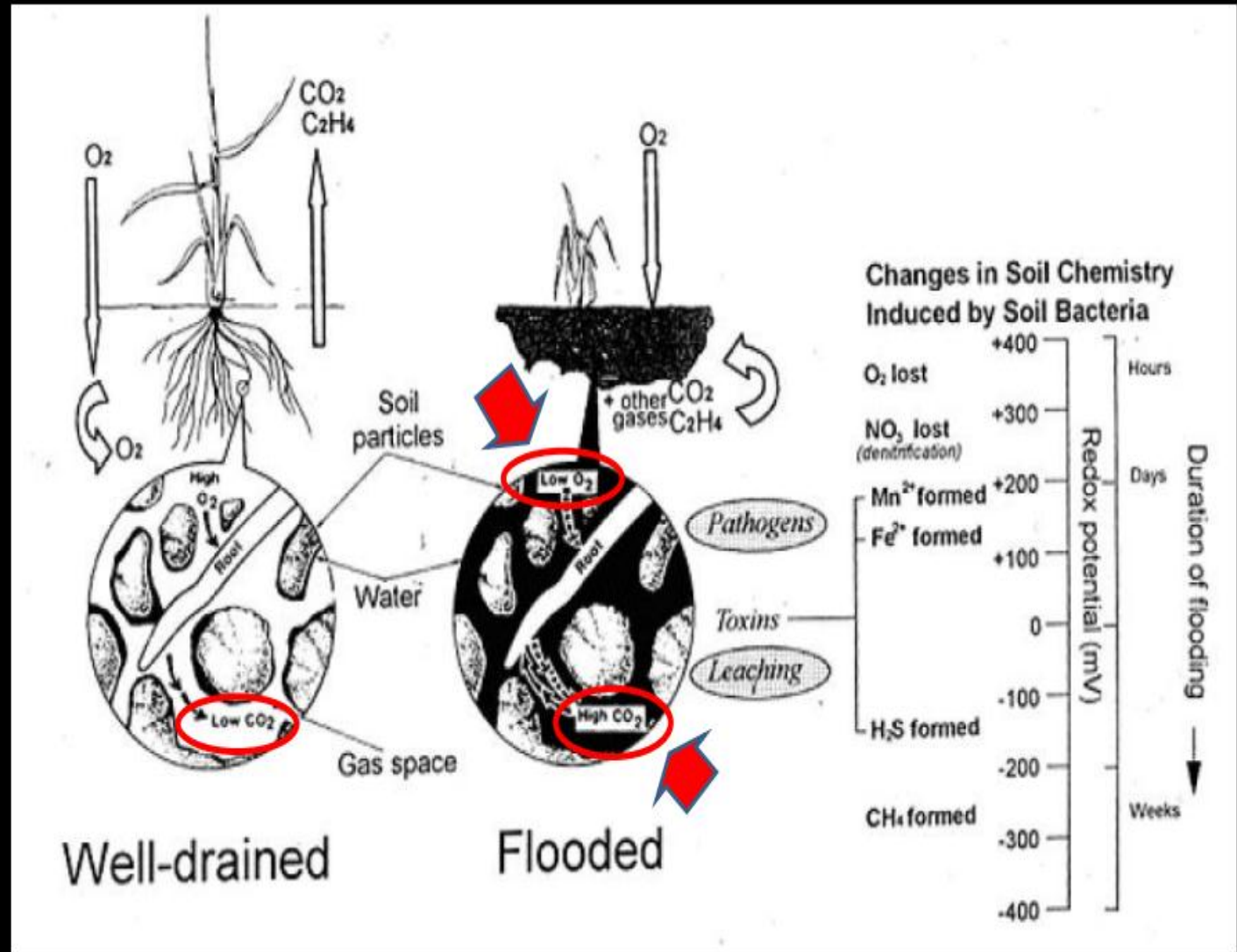
Jackson (2003)



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Biological activity in waterlogged soil

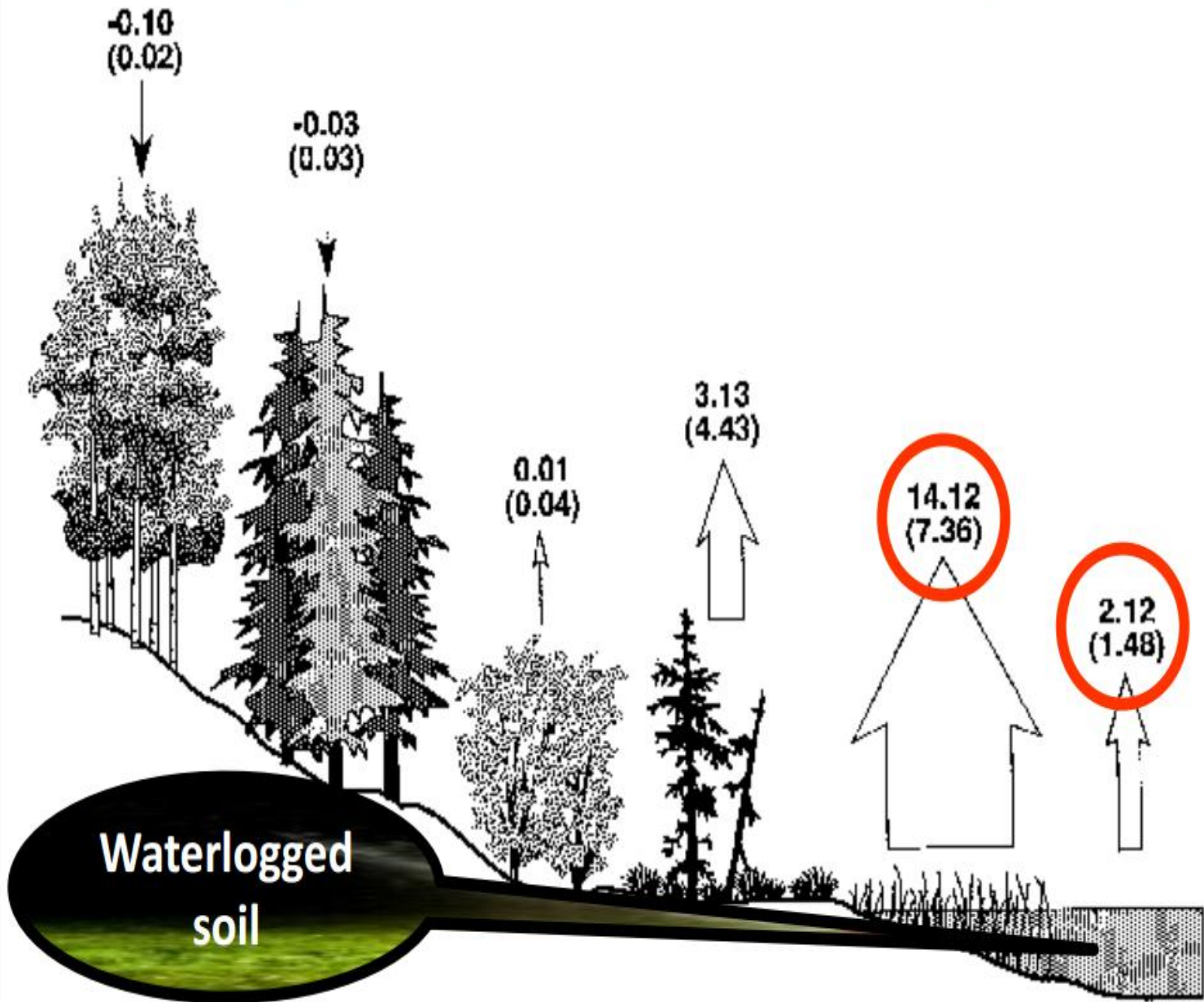


Jackson (2003)

Methane Emissions ($\text{mg m}^{-2} \text{hr}^{-1}$)



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Waterlogged soil



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Management of waterlogged soil

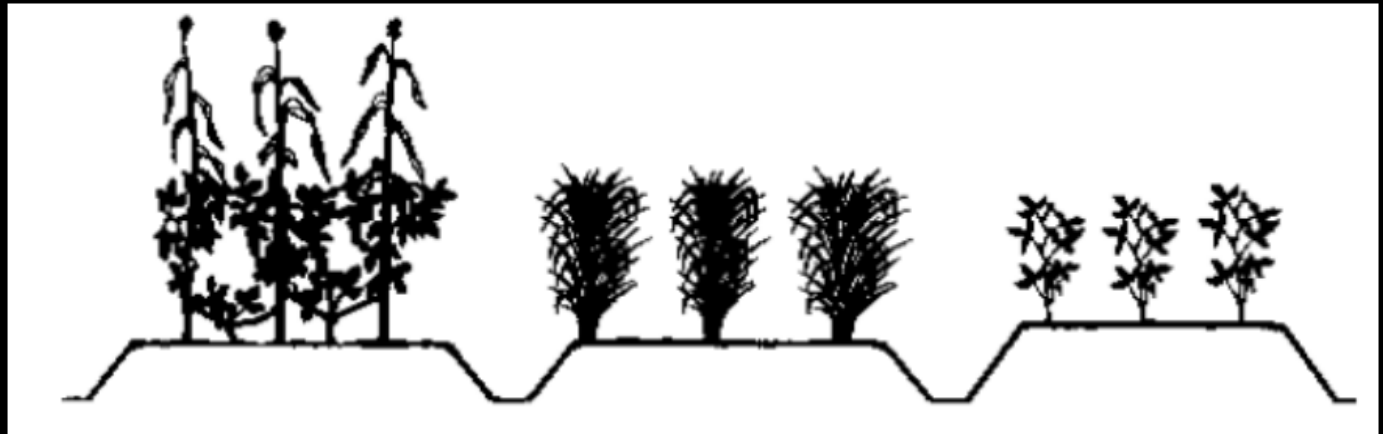
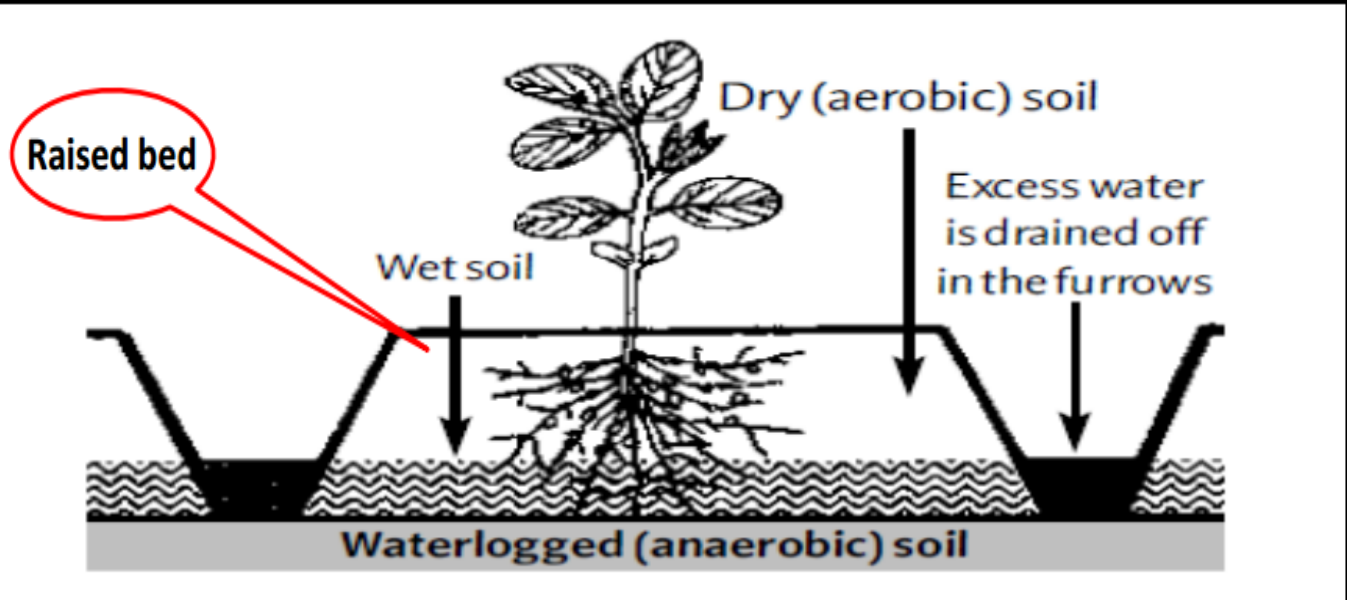
- ❖ **Leveling of land**
- ❖ **Mechanical drainage**
- ❖ **Controlled irrigation**
- ❖ **Flood control measures**
- ❖ **Plantation of trees having high transpiration rate**
- ❖ **Check the seepage in the canals and irrigation channels**
- ❖ **Selection of crops and their proper varieties**
- ❖ **Sowing on bunds or ridges**
- ❖ **Nutrient management**





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Sowing on raised bed in waterlogged soil



GRDC (2005)

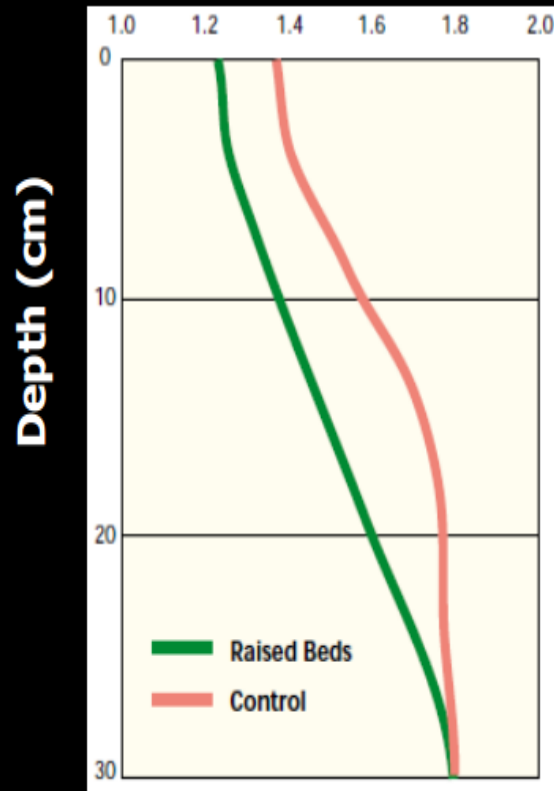


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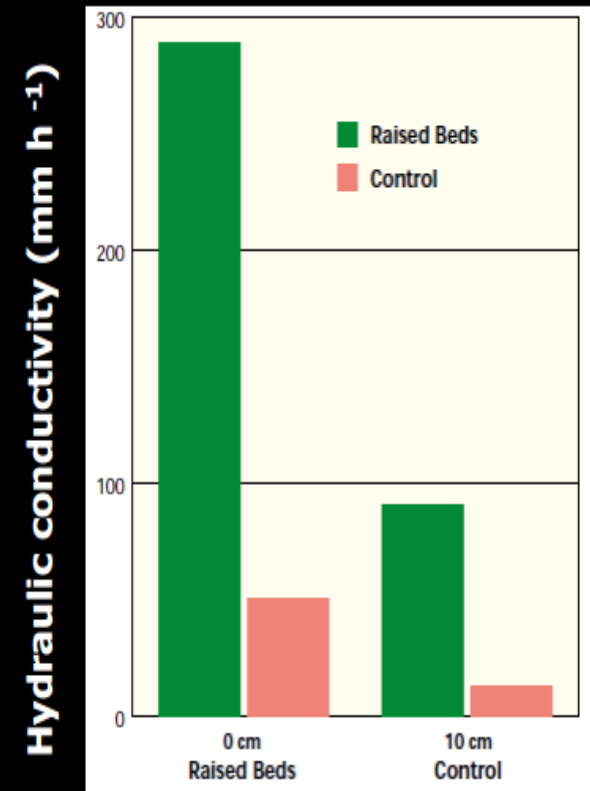
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Bulk density and Hydraulic conductivity increase as a result of raised bed farming system

Bulk density (g cm^{-3})



Geometric mean hydraulic conductivity



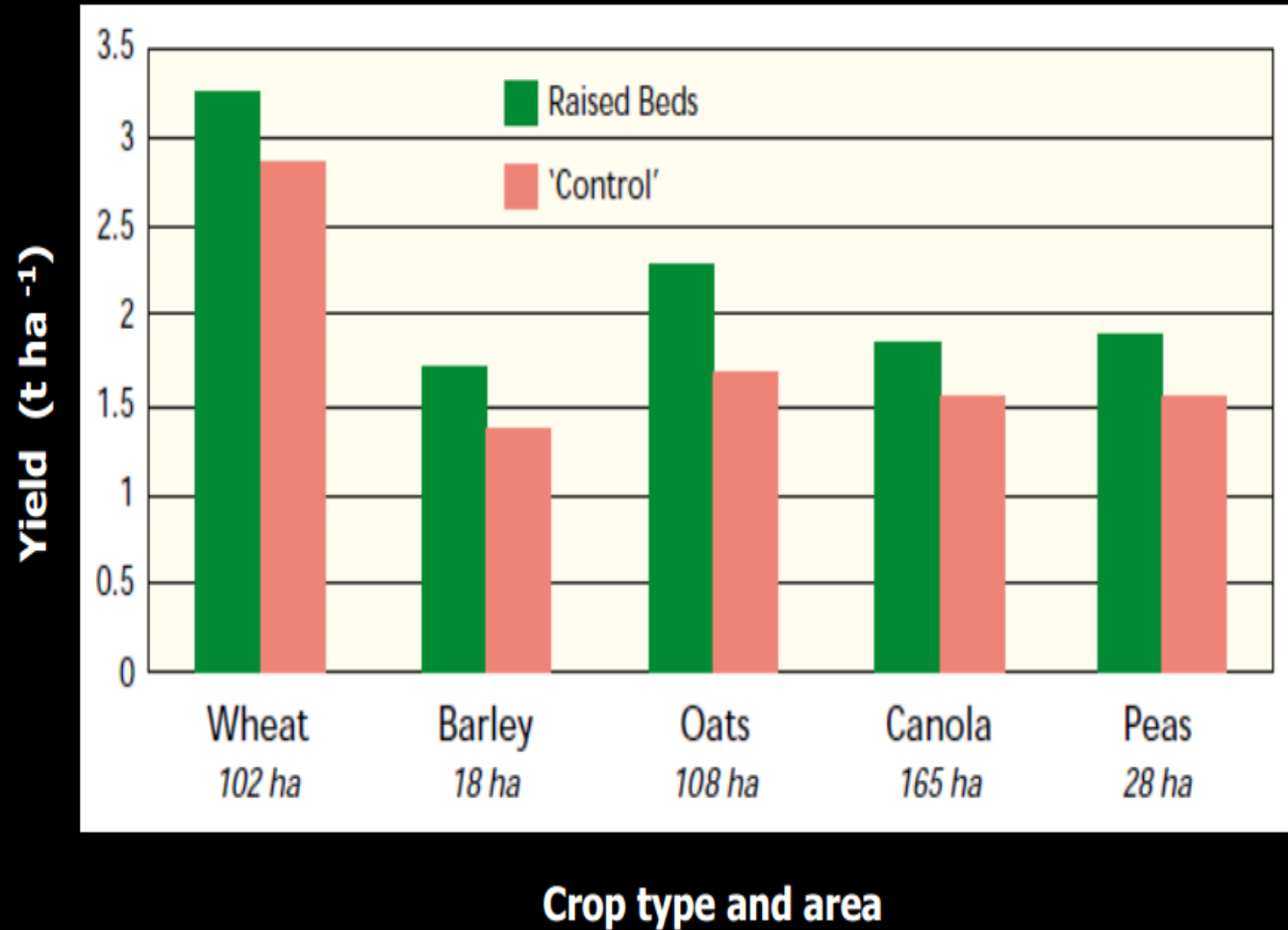
GRDC (2005)



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Raised bed production of different crops



GRDC (2005)



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Leveling of land





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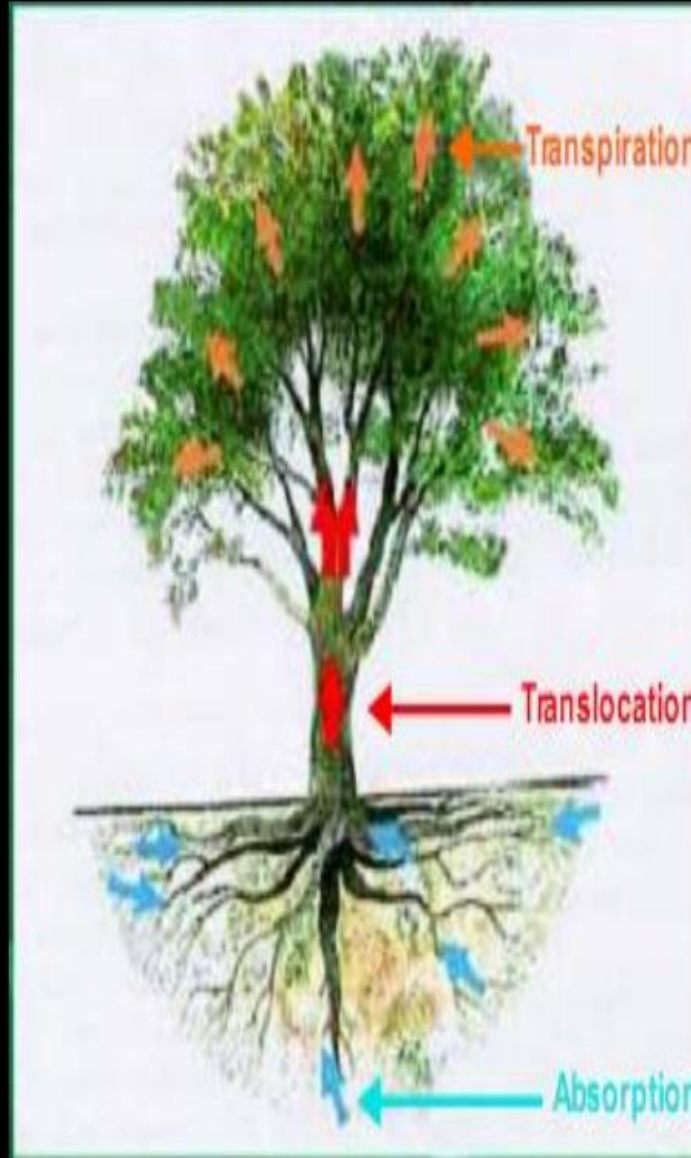
Bio-drainage





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What is bio-drainage?

**Pumping of excess soil water
by deep-rooted plants using
their
bio-energy**

Criteria of bio-drainage plants :

- **Fast growing**
- **Luxurious water consumption**



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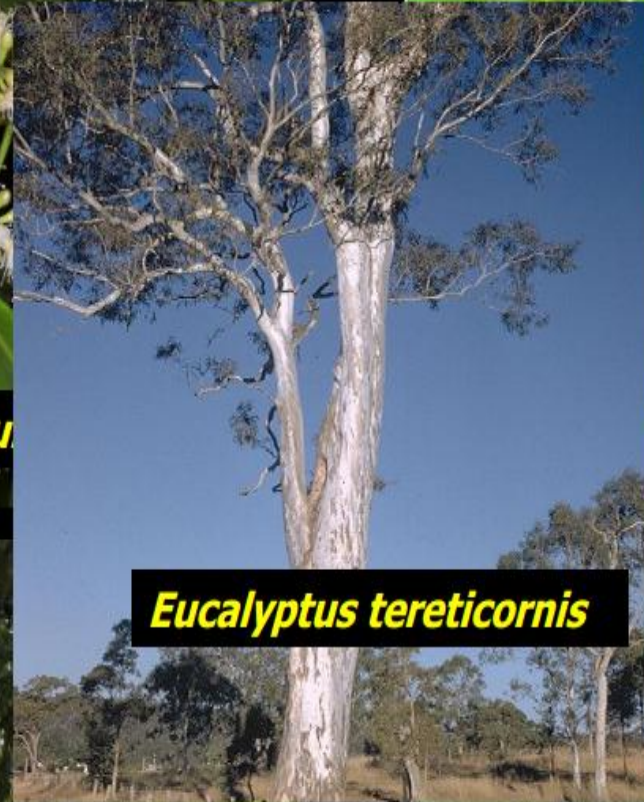
Different Bio-drainage plants



Syzygium cumini



Casuarina pinnata



Eucalyptus tereticornis



Terminalia arjuna



Casuarina glauca

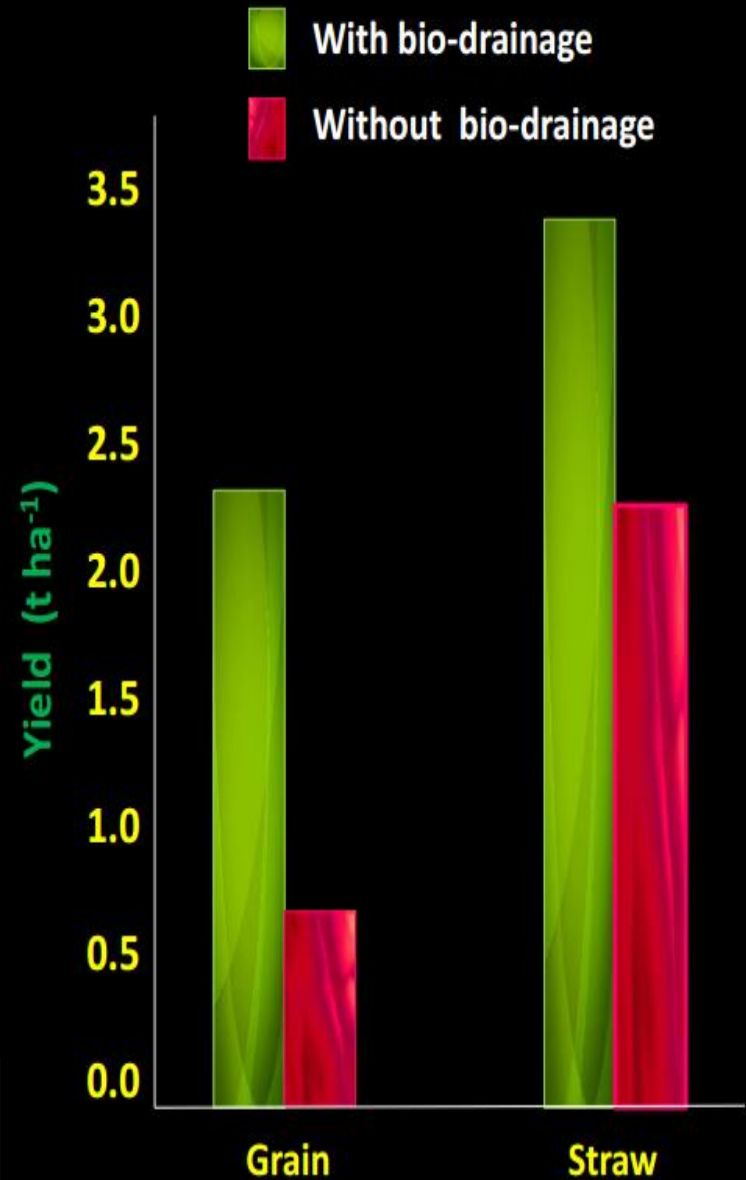


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Wheat yield obtained with and without *Eucalyptus tereticornis* plantation

The strip plantation
sequestered **15.5 t ha⁻¹**
carbon during the first
rotation 5 years 4 months

Wheat yield increase **3 - 4 times**
from adjacent waterlogged
soil without *Eucalyptus* sp.

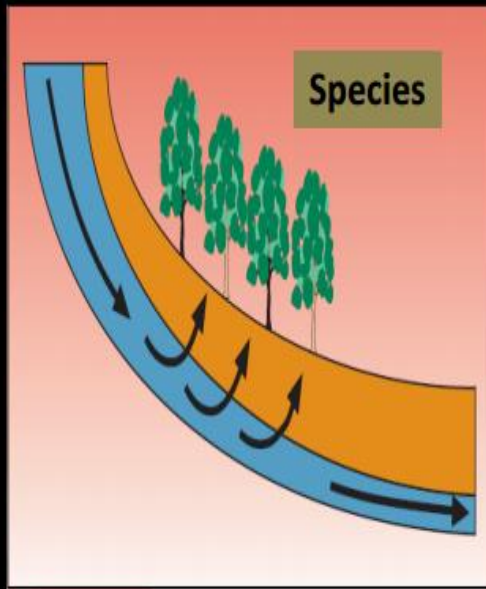
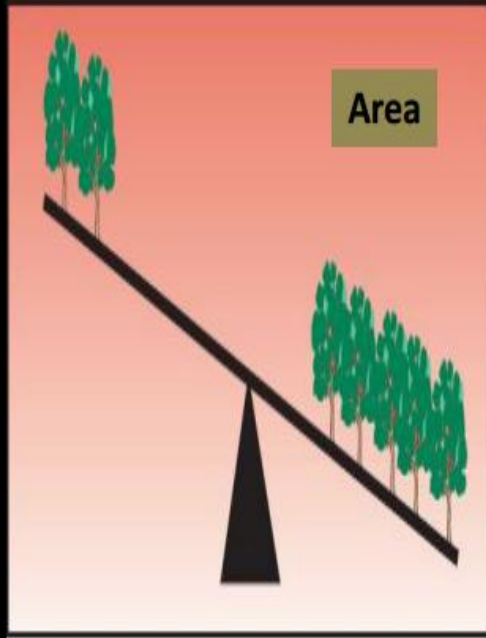


Ram (2011)



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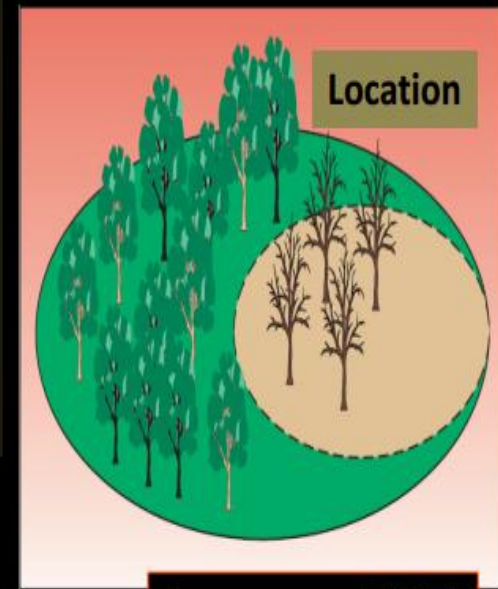
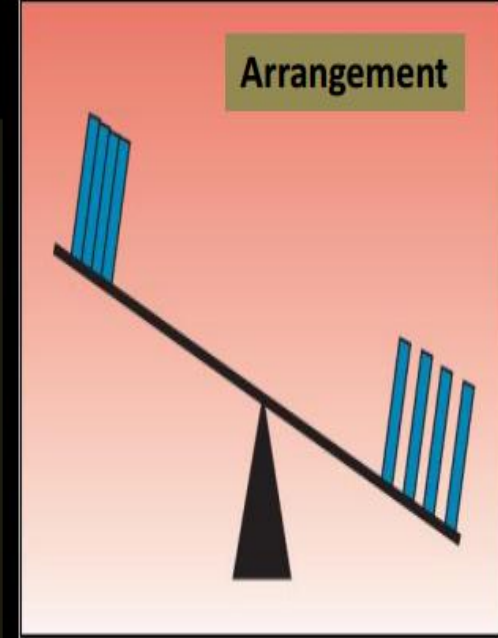
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**Factor balancing
recharge and
discharge of
groundwater**

**For minimizing
waterlogged soil**

- Reducing GW recharge**
- Increasing GW discharge**



Anonymous (1997)



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Sub-surface drainage

**Mostly practiced in areas
with high groundwater table**



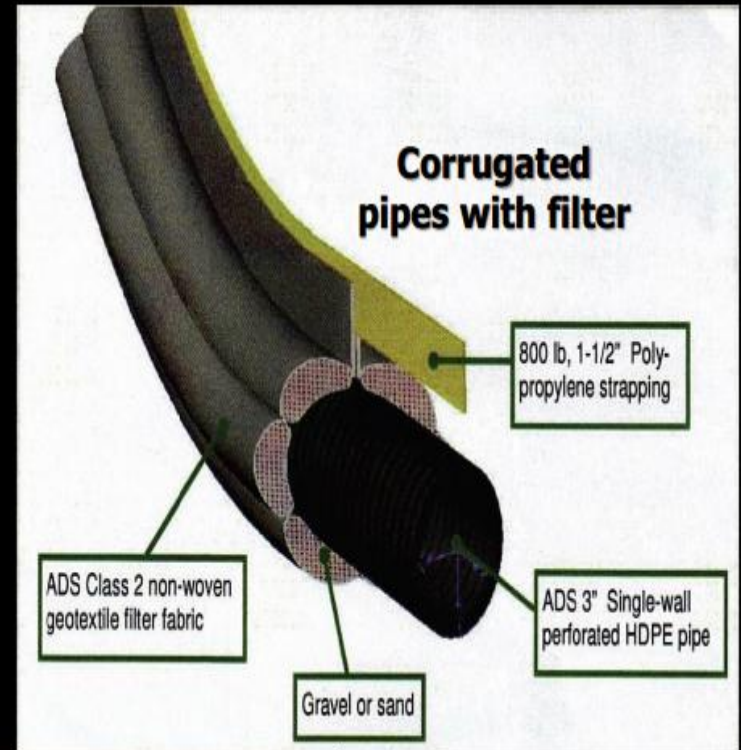


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Installation of pipes



Sump (for collection of drainage water)



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Increase in rice yield and cropping intensity as a result of waterlogging control through sub-surface drainage

Location	Before drainage			After drainage		
	EC (dS m ⁻¹)	Yield (t ha ⁻¹)	Cropping intensity (%)	EC (dS m ⁻¹)	Yield (t ha ⁻¹)	Cropping intensity (%)
Konakki	5.7	3.7	70	2.8	5.6	130
Uppugundur	4.8	4.3	77	2.9	5.6	165
Islampur	12	1.9	58.2	6.0	3.0	59.4
Sindhanur	8.4	2.2	141	2.6	3.7	191
Gorebal	6.5	2.3	-	0.9	7.2	-

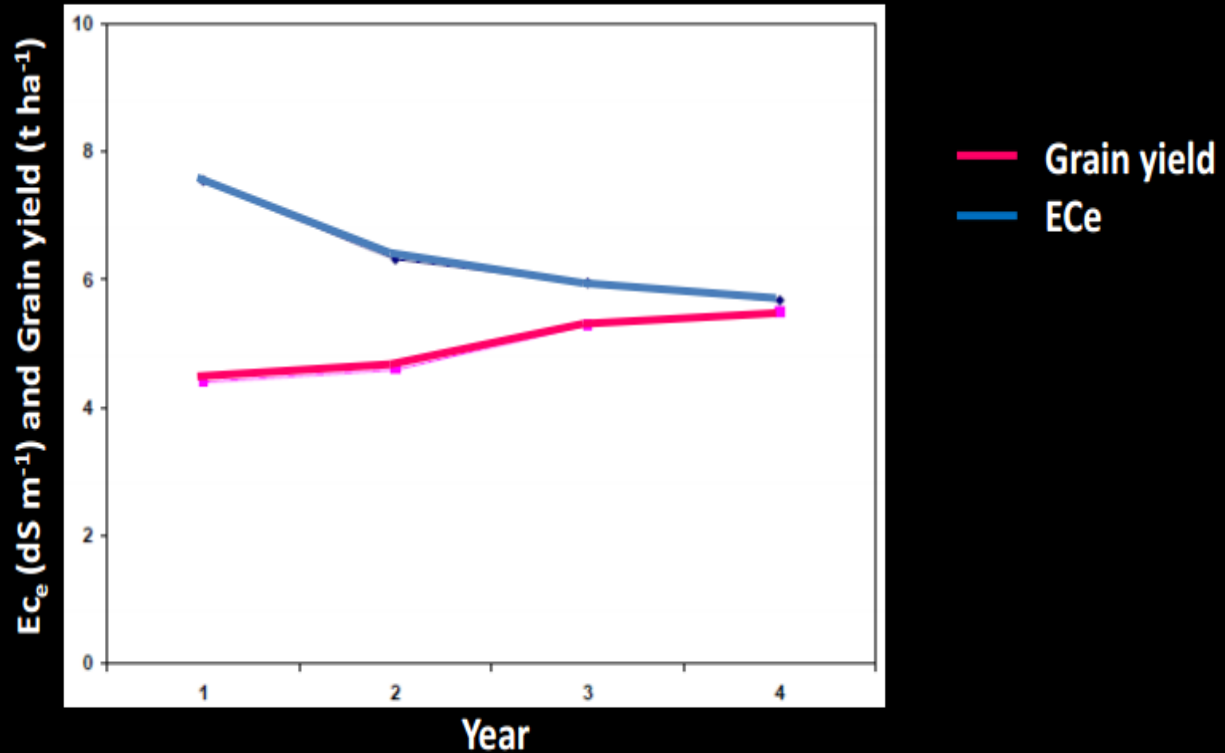
Gupta *et al.* (2004)



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Management with closed sub-surface drainage



Year	EC _e (dS m ⁻¹)	Grain yield (t ha ⁻¹)	Cropping intensity
2005	7.55	4.4	100
2006	6.32	4.6	125
2007	5.95	5.3	146
2008	5.68	5.5	160

Subba Rao *et al.* (2009)



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Wheat crop without and with drainage respectively



CSSRI Tech. Bull. (2008)



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Crops	Tolerant varieties	Adaptability	
		pH	Ec _e (dS m ⁻¹)
Rice	CSR 10, 11, 12, 13	9.8 – 10.2	6 – 11
	CSR 19, 23, 27, 30, 36	9.4 – 9.8	6 – 11
	CSR 1, 2, 3, 4, SR 26 B, Sumati	-	6 – 9
Wheat	KRL 1-4, 3-4, 210, 213, WH 157	< 9.3	6 – 10
	Raj 3077, KRL 19	<9.3	6 – 10
Barley	DL 200, Ratna, BH 97, DL 348	8.8 – 9.3	-
Indian musterd (Raya)	Pusa Bold, Varuna	8.8 – 9.2	6 – 8
	Kranti, CS 52, CS 330 -1	8.8 – 9.3	6 – 9
	CST 609B 10, CS 54	8.8 – 9.3	6 – 9
Gram	Karnal chana	< 9.0	< 6
Sugarbeet	Ramonskaaya 06, Maribo Resistapoly	9.5 – 10	< 6.5
Sugarcane	Co 453, Co 1341	< 9.0	< 10

CSSRI (2006)



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Why should we go for rice ?

- Minimal amendment requirement
- Stagnation of water
- Dilution of root zone salinity
- Extensive root system

Yadav (2006)



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Soil properties as affected by rice culture

Original soil		After experiment			
		Without rice		With rice	
pH	EC (dS m ⁻¹)	pH	EC (dS m ⁻¹)	pH	EC (dS m ⁻¹)
10.3	93.6	9.6	68.6	8.9	28.6
9.5	46.0	8.9	26.3	8.3	1.2
9.0	29.9	8.4	9.5	8.2	0.6
8.4	10.5	8.1	1.8	7.2	0.2

Chhabra and Abrol (1977)



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Aerenchyma formation , but HOW?

Waterlogged conditions

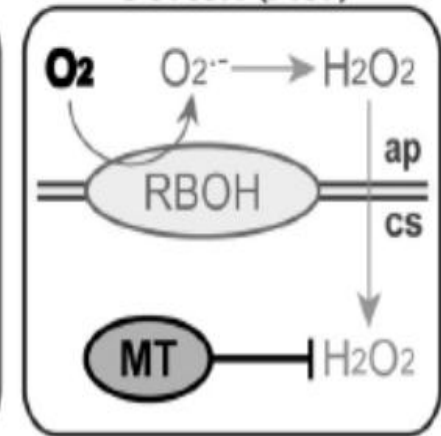
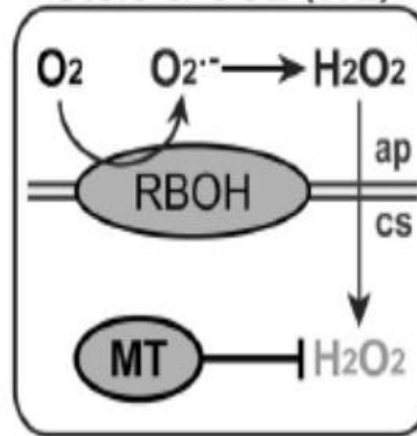
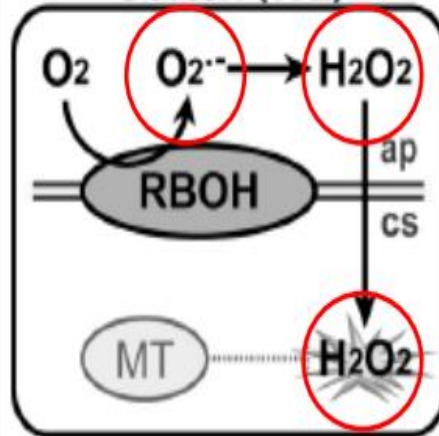
Aerobic conditions

Ethylene biosynthesis & accumulation

Cortex (WL)

Stele & OCL (WL)

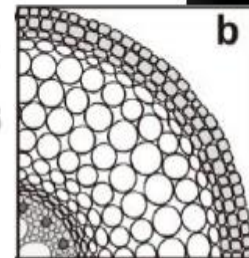
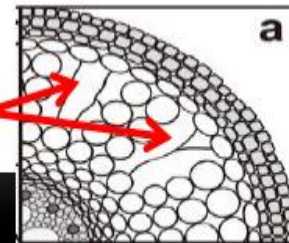
Cortex (Aer)



Cell death and cell lysis

No cell death and cell lysis

Aerenchyma formation



Nishiuchi (2012)



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Orange Fe (iron oxide) precipitation on rice roots

When rice is grown in these soils they escape Fe toxicity by Fe precipitation due to oxygen diffusion from roots due to extensive aerenchyma.



Orange precipitation and black dots on rice roots due to (iron oxide) MnO_2 during waterlogging condition in India

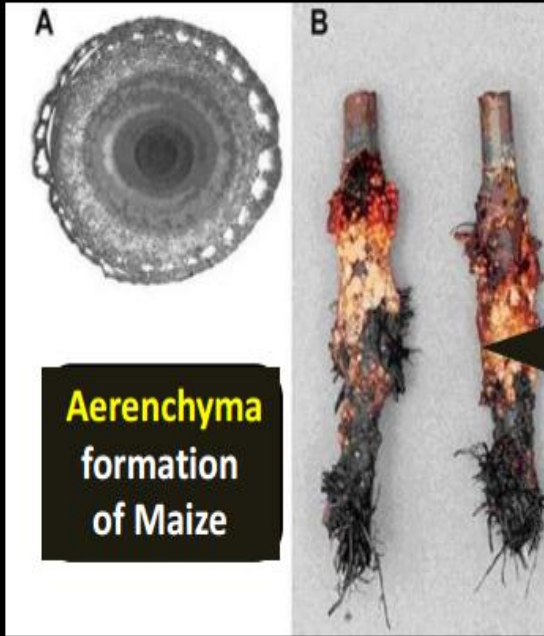
Growing rice in WL soils could be a cheap way to evaluate potential Fe toxicity in these soils.

DTPA-Fe increased 6x; DTPA - Mn increased 15x in these WL soils after 21d (Yaduvanshi *et al.*).



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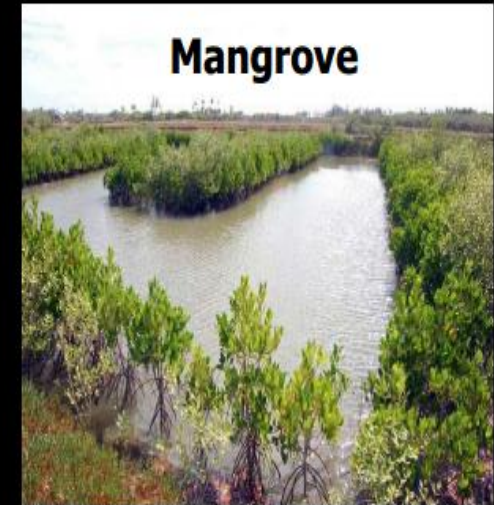
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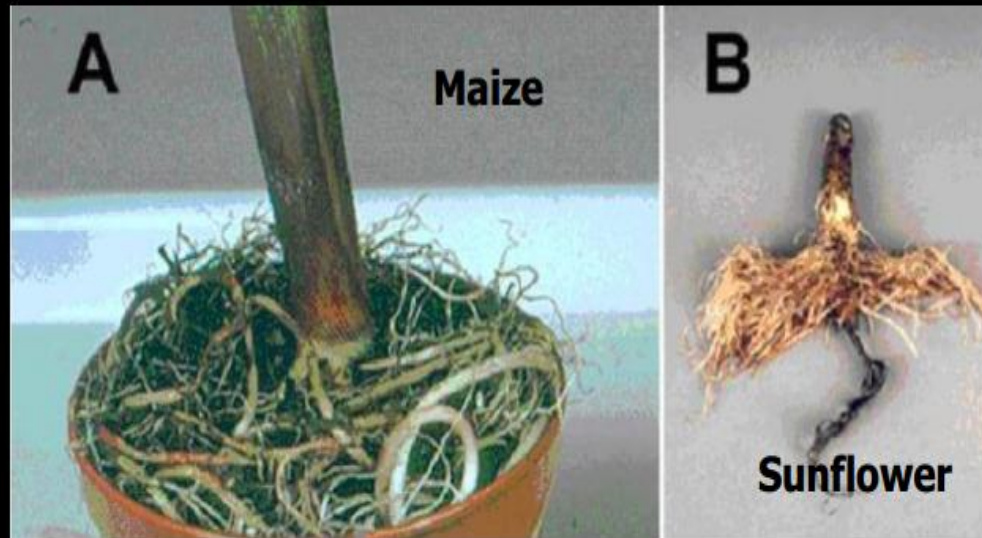
Aerenchyma
formation
of Maize

Hypertrophic
lenticels at the
stem base of
young Apple
plants

Survival of plants



Mangrove



A Maize

B Formation of
adventitious
roots at the soil
surface by plants

Sunflower

Jackson (2003)



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Nutrient management





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Nutrient management in waterlogged soil

Treatment	Ammonia loss(%)	Soil pH(water)
T0	0	5.40
T1	42.87	7.21
T2	26.39	6.95
T3	19.85	7.03
T4	25.28	7.09

T0	Soil alone
T1	Urea without additives
T2	Urea+175 ml sago waste water+0.75g zeolite
T3	Urea+175 ml sago waste water+1.00g zeolite
T4	Urea+175 ml sago waste water



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Nutrient management in waterlogged soil

Treatment	NH ₄ -N (ppm)	NO ₃ -N (ppm)
T0	12.07	1.55
T1	78.09	22.80
T2	177.87	34.00
T3	166.50	38.76
T4	126.78	24.76

T0	Soil alone
T1	Urea without additives
T2	Urea+175 ml sago waste water+0.75g zeolite
T3	Urea+175 ml sago waste water+1.00g zeolite
T4	Urea+175 ml sago waste water

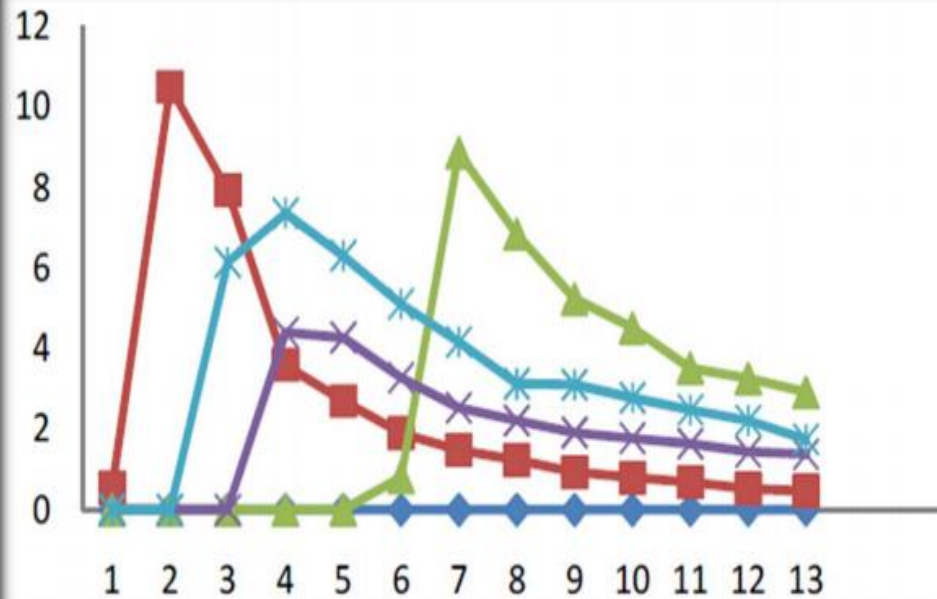


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Minimizing ammonia volatilization in waterlogged soils through mixing of urea with zeolite and sago waste water

Daily ammonia loss
(% of applied nitrogen)



Treatments



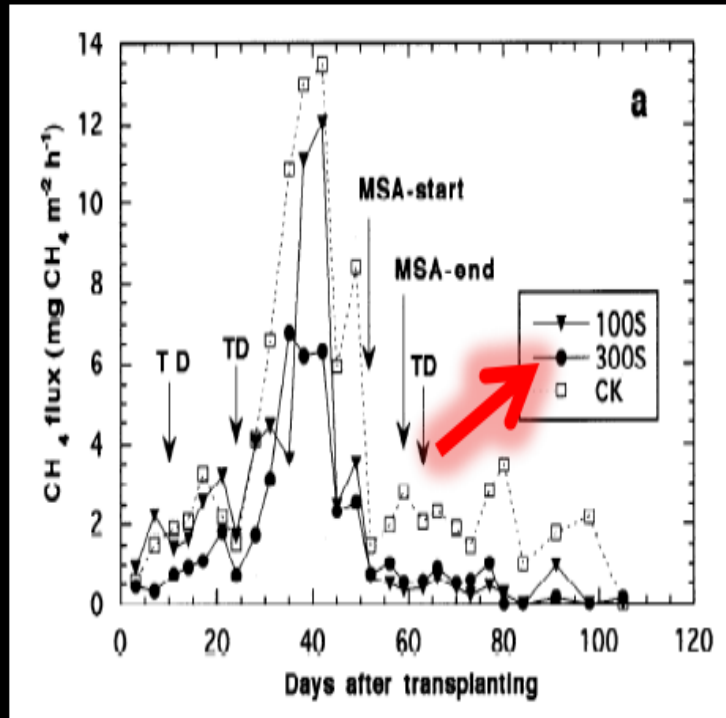
Days of volatilization (days)



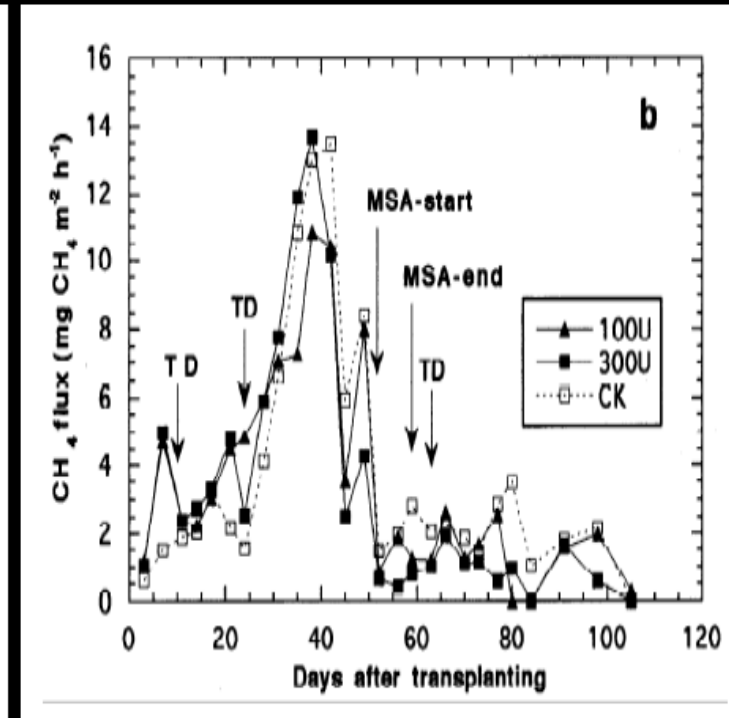
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Decrease in methane emission from waterlogged soils resulted nutrient management by sulphur containing nitrogenous fertilizers



Ammonium sulphate



Urea

□ Application of sulphate containing fertilizers control CH₄ release from waterlogged soil



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Agro-ecological interactions in “Rice-Fish” culture

- **Improve fertility of the ecosystem by increasing nutrient cycling and availability**
- **Organic matter, N, K were all higher in the fields of rice-fish culture**
- **Increases of N concentration in rice grain by 5% and N uptake by 10%**
- **It was demonstrated that reduction of N loss to some extent from rice-fish cultured field by lowering pH significantly (0.3-0.6 units)**
- **Application of triple superphosphate (100 kg ha^{-1}) cause 1.3 t ha^{-1} higher yield in rice -fish ecosystem than control**

IRRI report (1996)



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Conclusions

- ❖ **Waterlogging causes lowering of redox potential, neutralized soil pH, N P K deficiency and micronutrient toxicity.**
- ❖ **Except rice, yield of other crops severely affected by waterlogging and submergence.**
- ❖ **Waterlogging can be efficiently control by forming different land configuration, mechanical as well as bio-drainage, controlling irrigation and different flood control measures.**
- ❖ **Tolerant or resistant varieties and proper nutrient management would be much more effective during management of waterlogged soil.**



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Path ahead ...

- ❑ Detailed study about the interaction mechanisms of microbes and different soil constituents in waterlogged soil is needed in order to have a better understanding of microbial activity in waterlogged soils.
- ❑ Different new methods should be innovated to control the ground water recharge from different water resources.
- ❑ Further study should be required to estimate the release characteristics of different micronutrients.
- ❑ Different new methods should be introduced for running cultivation practices during waterlogged situation.