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Reduction of Fe with Application of Saturated Soil Culture Technology and Biomass Ameliorant on Organic Rice Farming in Tidal Swamp

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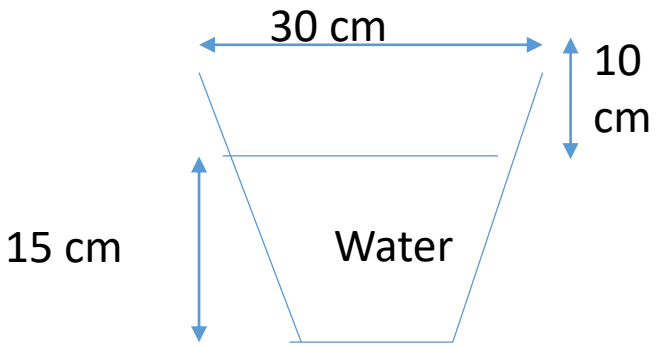
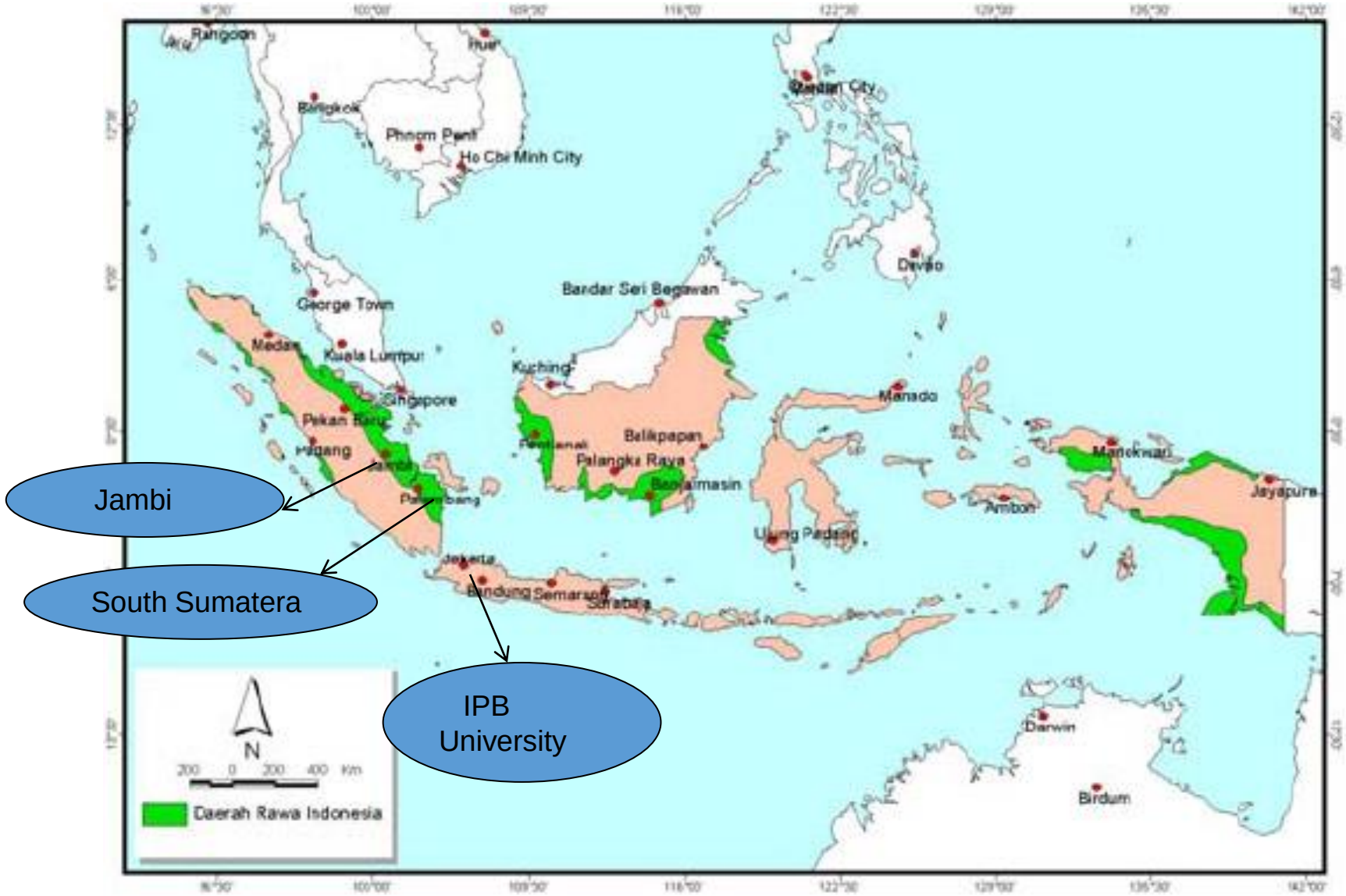
INTRODUCTION

- Saturated Soil Culture (SSC) or Budidaya Jenuh Air (BJA)
- SSC is a cultivation technology that gives continuous irrigation and maintains water depth constantly and makes soil layer in saturated condition (Nathanson et al. 1984; Troedson et al. 1984; Lawn 1985)
- Indonesia has Tidal Swamps area, about 20.1 million ha and 9.53 million ha suitable for agriculture (Noor and Sabur 2007).
- The constrains of food crop cultivation on tidal swamp are : high pyrite (FeS2) , Al, Fe, and Mn, and low pH, N, P and K availability
- Reduction of Fe will be conducted with : 1) oxidation process, 2) chelating, and 3) tolerance rice variety
- This SSC technology appropriate to prevent pyrite reduction and increased rice productivity on tidal swamp (Ghulamahdi et al., 2009)
- Water depth of SSC for rice is about 10 cm under soil surface



The Distribution of Swamps Area in Indonesia and Research Location



Swamp Area in Indonesia

Location	Swamp Area (ha)			Reclamation Area by The Government (ha)		
	Tidal Swamp	Non-Tidal Swamp	Total	Tidal Swamp	Non Tidal Swamp	Total
Sumatera	6,604, 000	2,766 000	9,370,000	615,250	279,480	894,730
Kalimantan	8,126,900	3,580,500	11,707,400	219,950	192,190	412,140
Papua	4,216,950	6,305,770	10,522,720	0	6,000	6 ,000
Sulawesi	1,148,950	644,500	1,793,450	0	2,000	2,000
Total	20,096,800	13,296,770	33,393,570	835,200	479,670	1,314,870

Soil Chemical in Tidal Swamp

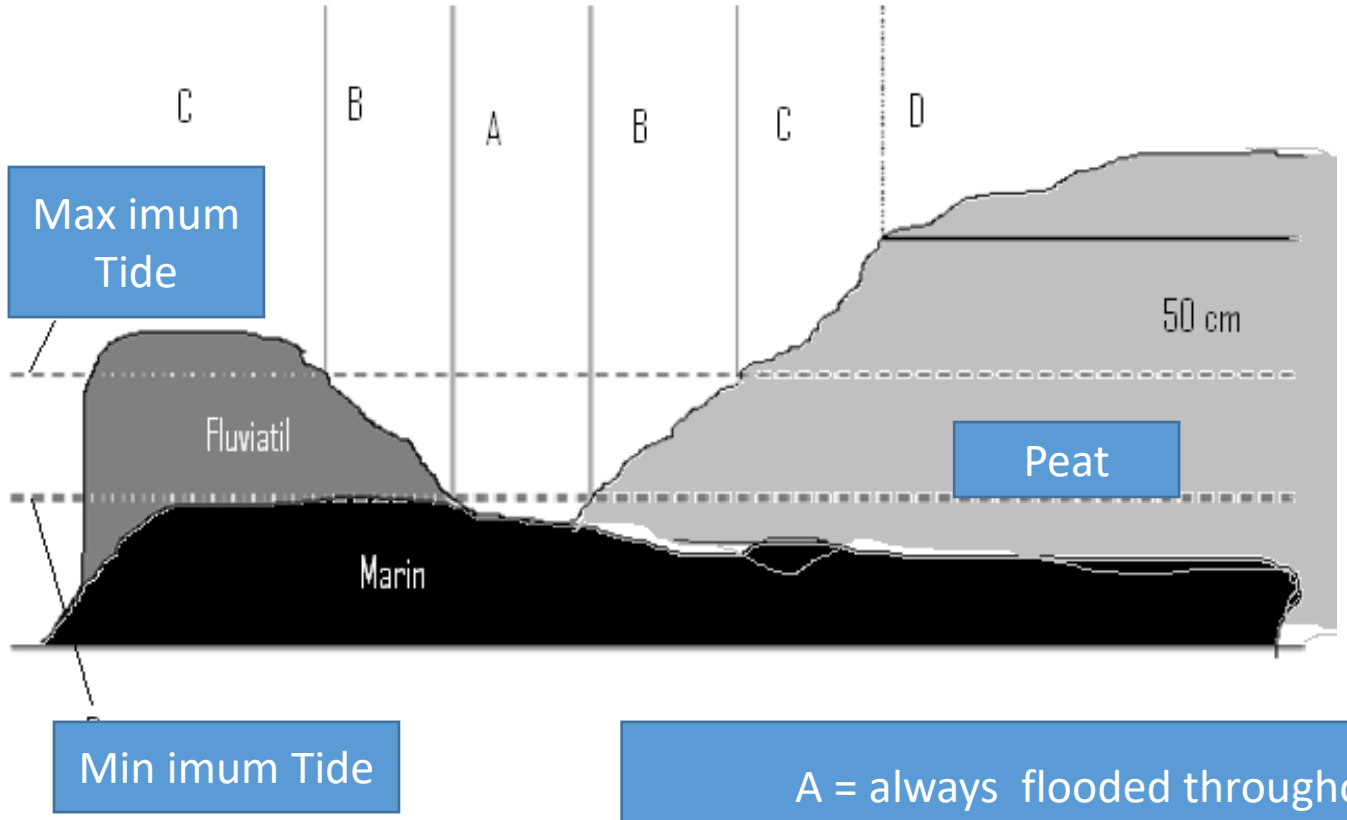
Problem of Food Crop Cultivation on Tidal Swamp

- High Pyrite
- Figure of Pyrite

Gray colored, reaction with H_2O_2 will be effervescent

oxidation will be red browned

Research Location on C Overflow Type



A = always flooded throughout the year (rice-rice)
B = sometimes flooded in rainy season (rice-soybean)
C = water depth under 50 cm from soil surface (rice-soybean)
D = not overflowing (perennial crop: rubber, oil palm)

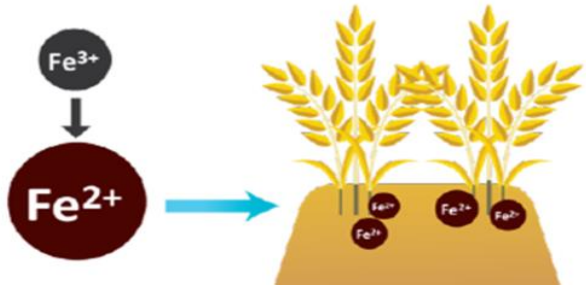
METHOD

- This research was conducted in Banyuasin District, South Sumatera Province; and in Tanjung Jabung Timur District, Jambi Province from 2009-2022.
- The objective of this research is to study: 1) the rice adaptation mechanism to the soil with high Fe content, and 2) the efficiency of production input of rice cultivation with biomass ameliorant, 3) the farmer's response to the application of innovation.
- This research used field and greenhouse experimentation designs.
- This research consisted of 1) a study of the rice adaptation mechanism, 2) the response of rice varieties under Saturated Soil Culture (SSC) and Flooded Culture (FC), and 3) the effect of biomass ameliorant on rice productivity. 4) dissemination of technological innovation to the farmer.

RESULT AND DISCUSSION

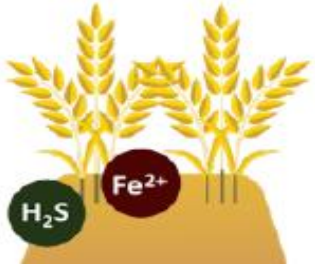
Rice Cultivation with Flooded Culture

1



- In flooded method, there is a reduction process which changes Fe^{3+} into Fe^{2+}
- Fe^{2+} will enter the roots and poison the plants
- In some tolerant rice, a part of Fe^{2+} will be deposited in the form of Fe^{3+} (Fe_2O_3), seen as brownish-brown plaques in roots area

2



Poisoning of paddy plants in reductive conditions can also be caused by the presence of H_2S

3

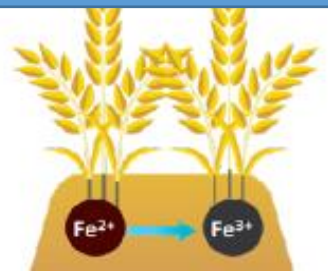
Reduction of acid-rich sulphate soil

$$Fe_2O_3 + {}^1/_2CH_2O + 4H^+ \rightarrow Fe^{2+} + {}^1/_2CO_2 + {}^5/_2H_2O$$

Reduction of sulphate

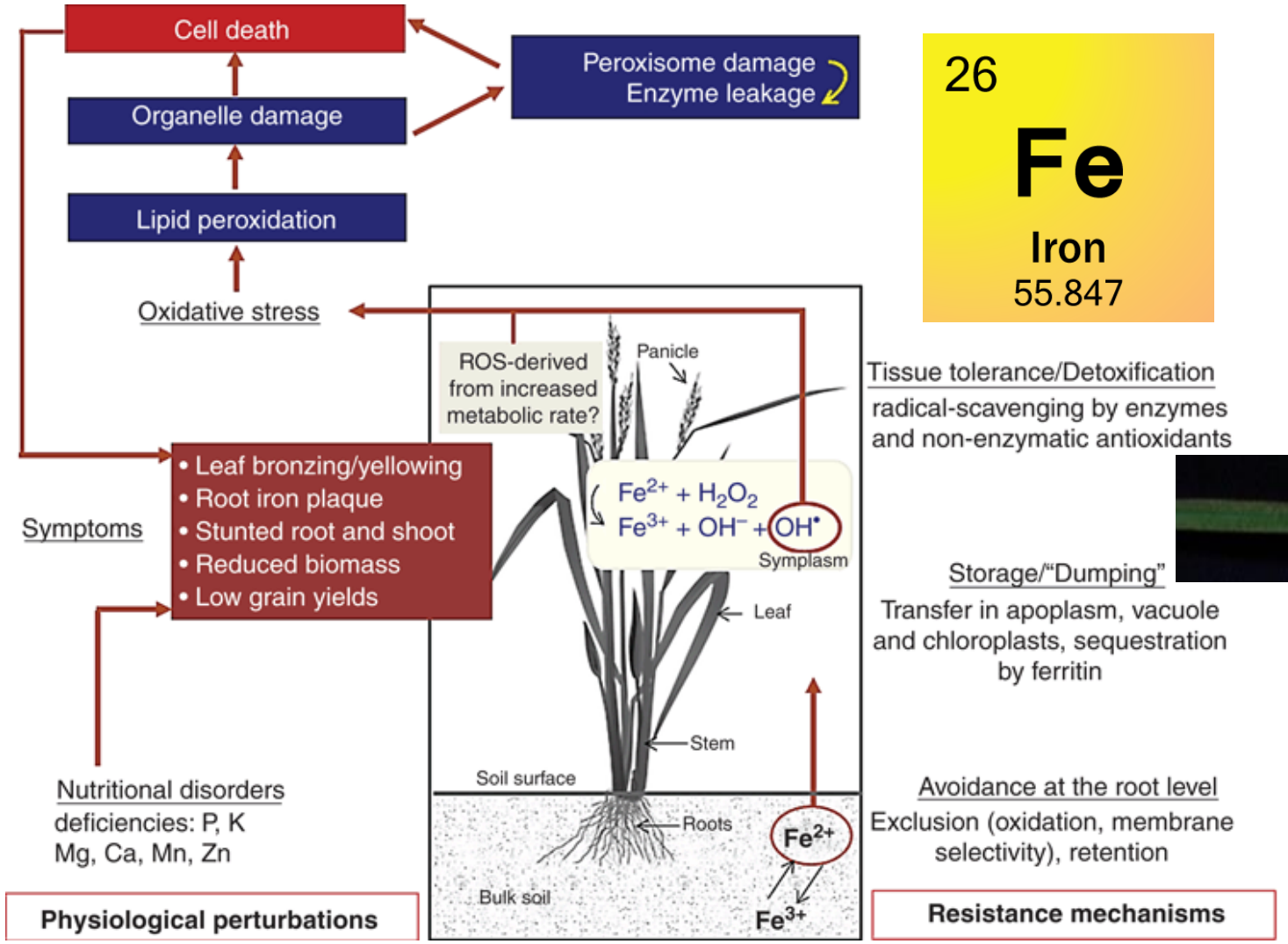
$$SO_4^{2-} + 2CH_2O + 2H^+ \rightarrow H_2S + 2CO_2 + 2H_2O$$

Rice Cultivation with Saturated Soil Culture



With BJA (SSC), Fe^{2+} will precipitate into Fe^{3+} (Fe_2O_3) in the soil layer thus lowering the level of paddy poisoning against Fe^{2+}

The growth of rice plants in tidal mineral swamp with SSC is better than with stagnant flooded condition

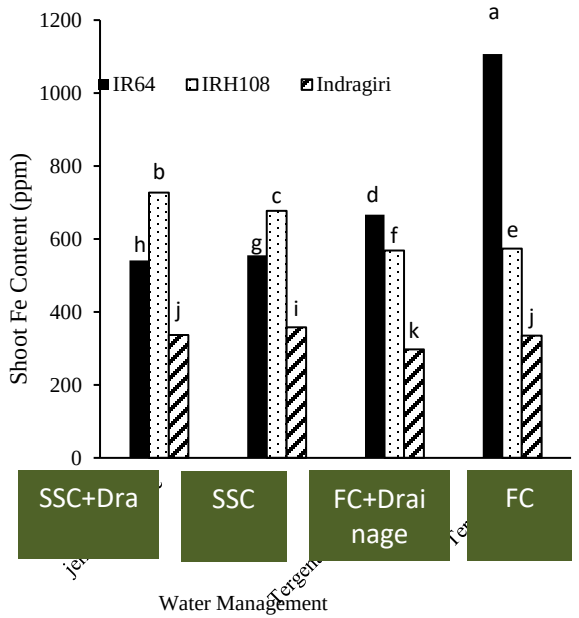


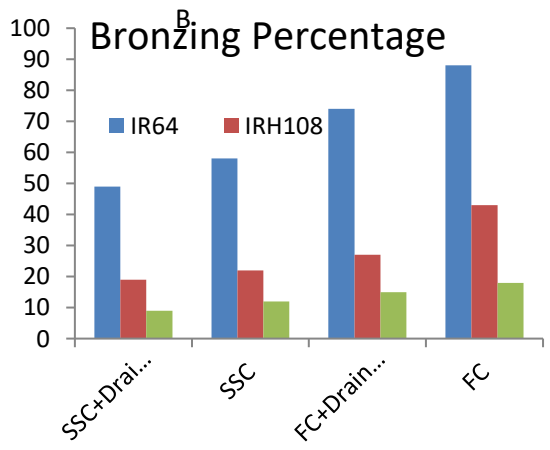
26
Fe
Iron
55.847

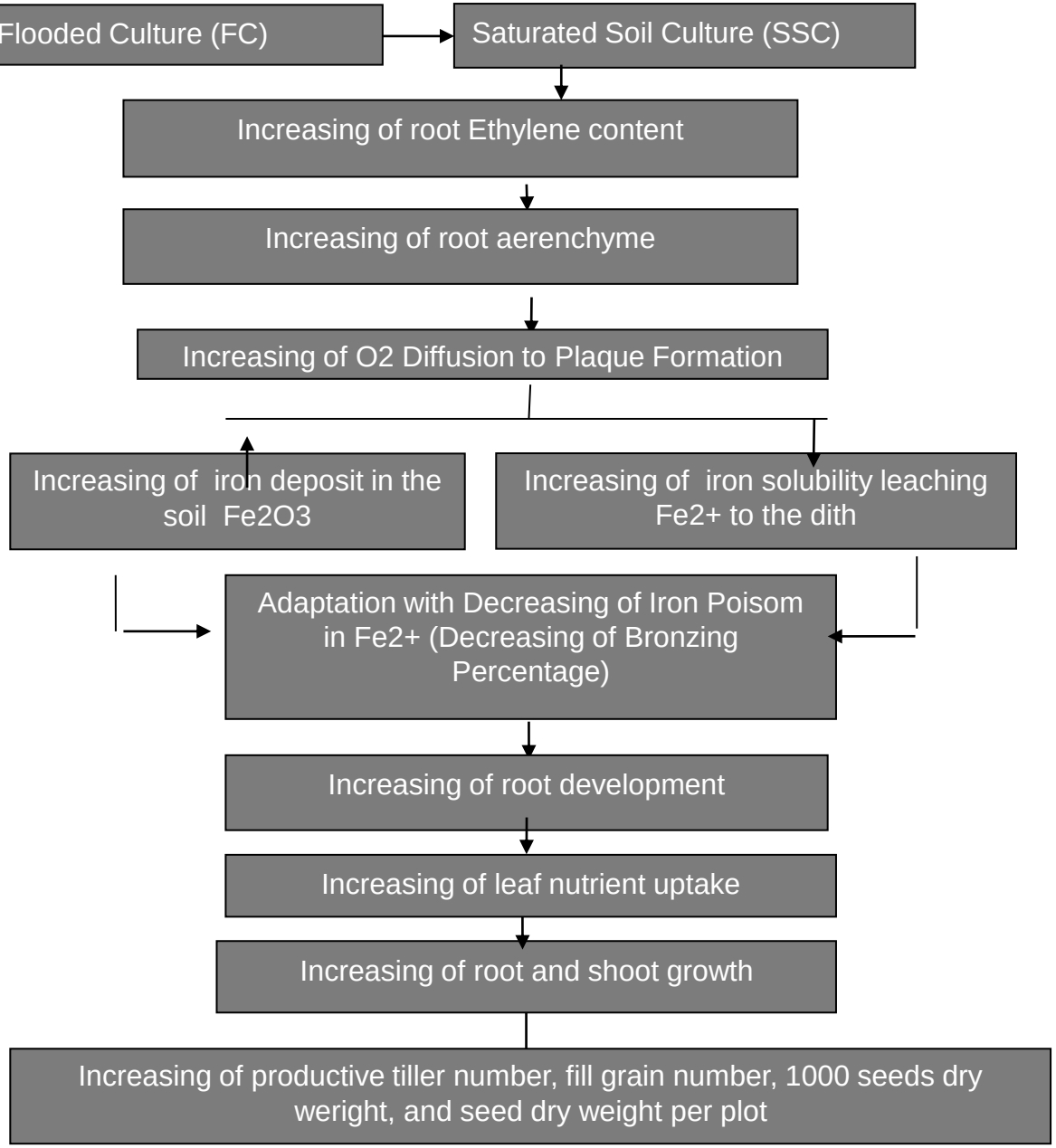
Bronzing

(Onaga *et al.* 2016)

Physiological Change of Rice under Saturated Soil Culture from The Flooded Culture

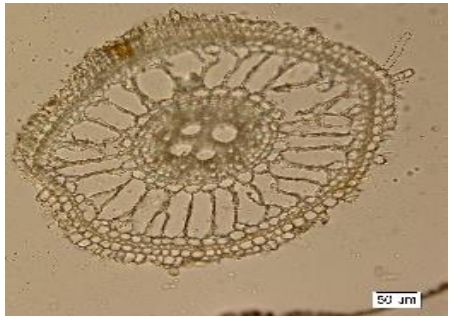






Productivity of Rice under Saturated Soil Culture and Flooded Culture on Soil Fe upper 20 000 ppm

SFC



SSC

	Water Management			
Genotype	Saturated Soil Culture with Drainage	Saturated Soil Culture without Drainage	Flooded Culture with Drainage	Flooded Culture without Drainage
Grain Dry Weight (t ha^{-1})				
IR64	4.41^{f}	4.56^{ef}	0.00^{h}	0.00^{h}
IRH108	5.46^{c}	4.81^{de}	3.80^{g}	0.00^{h}
Indragiri	6.23^{b}	5.96^{b}	6.83^{a}	5.13^{d}

Mechanism of Tolerance Rice Variety on High Fe

- Tolerance Mechanism :
- 1. Excluder Type (Fe^{2+} was changed to plaque in Fe_2O_3 formation in rice root)
- 2. Includer Type (Fe^{2+} enter to the root, and then to the leaf, in the leaf Fe^{2+} was neutralized by SOD enzime (super oxide dismutase, and result H_2O_2 was changed to H_2O and triplet Oxigen, so it is not poison to the rice plants
- On sensitive rice variety to the Fe^{2+} will make bronzing in the leaf as polyphenol compound
- Indragiri variety was predicted through Excluder and includer Mechanism

Ameliorant of Straw Biomass

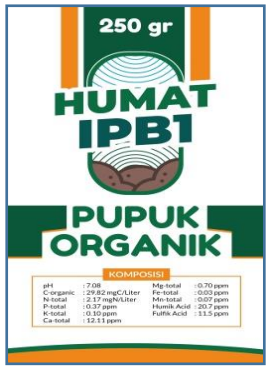
Soil Chemical Change

Soil Chemical	Soil Before Treatment	Straw Bimass without ploughing	Straw Biomass with 1 ploughing	Straw Biomass with 2 ploughing
pH	3.9	4.2	6.2	5.7
C (%)	4.01	3.69	10.83	11.08
N (%)	0.21	0.20	0.42	0.43
C/N	19	18	26	26
P_2O_5 Olsen	16.04	-21.33	51	37
K_2O	83	71	608	200
Ca (cmol(+) kg^{-1})	0.70	1.10	10.50	5.83
Mg (cmol(+) kg^{-1})	0.71	0.56	0.67	0.62
K (cmol(+) kg^{-1})	0.08	0.07	0.64	0.25
Na (cmol(+) kg^{-1})	0.15	0.12	0.16	0.22
CEC (cmol(+) kg^{-1})	8.39	7.91	17.65	15.31
Base Saturation(%)	20	23	67	45
Al (cmol(+) kg^{-1})	6.09	5.63	0	0
Fe (%)	2.80	2.77	1.98	1.47
S (%)	0.07	0.01	0.20	0.20
Pirit (%)	0.38	0.38	0.13	0.03
Humic acid %)	7.29	7.27	12.42	16.45

The application of straw biomass increased of rice productivity and decreased of N, P, K dose until 50 %

Rice Productivity on The Different Water Management and Ameliorant on Soil Fe 15 000 ppm

Water Managements	Ameliorant	Productivity (ton/ha)
Saturated Soil Culture without Drainage	Without Ameliorant	3.82def
	Peat Humic Acid	6.61a
	Dolomit	4.44cd
	Cow Dung Fertilizer	4.55c
Saturated Soil Culture with Drainage	Without Ameliorant	3.84def
	Peat Humic Acid	5.60b
	Dolomit	4.10def
	Cow Dung Fertilizer	4.35cd
Flooded Culture without Drainage	Without Ameliorant	3.38fg
	Peat Humic Acid	4.0cdf
	Dolomit	3.66efg
	Cow Dung Fertilizer	3.47efg
Flooded Culture with Drainage	Without Ameliorant	2.56h
	Peat Humic Acid	3.37fg
	Dolomit	3.06gh
	Cow Dung Fertilizer	3.13gh



Note :
1. Humic acid : 30 kg/ha
2. Dolomit : 2 ton/ha
3. Cow Dung Fertilizer : 2 ton/ha
4. Variety : Inpara 2

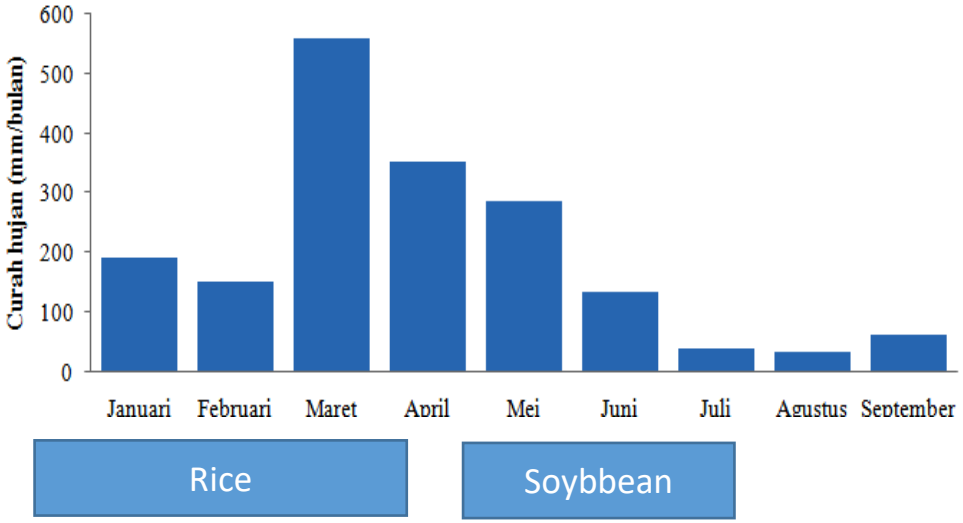
Rice Variety Productivity under Saturated Soil Culture on The Different Soil Fe

Variety	Rice Productivity (ton/ha)	
	Soil Fe 3400 ppm	Soil Fe 6200 ppm
IR 64	6.55 b	4.51b
Sertani	8.35ab	6.20ab
Inpari 16 Pasundan	9.35a	7.66a
Inpara 2	7.73ab	5.90ab

Macro, Micro, and SSC Water Management and Cropping Pattern

Secondary Canal

Tertiary Canal



SECONDAIR		
TERTIER	SSC	TERTIER 800 m
	SSC	
	SSC	
	SSC	
	SSC	
	SSC	
	SSC	
	SSC	
SECONDAIR (400 m)		

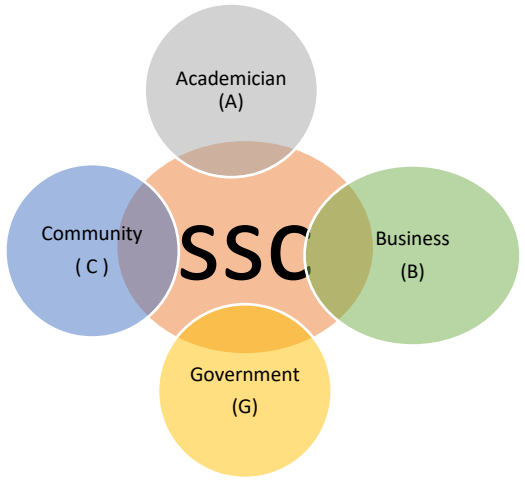
- 1) Distance of between secondary canal 800 m
- 2) Distance of between tertiary canal 400 m
- 3) Distance of between quartiary 100 m
- 4) Distance of between SSC canal 4 m .
- in overflow type –A : continuous rice-rice
- In overflow B : continuous rice-rice or rice-soybean or rice-corn
- In overflow-C : rice-soybean or rice corn

Activity Step of Saturated Soil Culture for Organic Rice Farming

1. Improvement of micro and macro canal water management (primer, secondary, tertiary, quartiary)
2. Making of SSC ditch
3. Improvement of water inlet and outlet stopper
4. Cropping pattern arrangement (rice-soybean)
5. Using of mechanization equipment for canal improvement , ditching, land preparation, planting, harvesting, and drying
6. Land preparation with minimum tillage
7. Biomass or hummic acid ameliorant
8. Using Bio-fertilizer (Inoculant FMA, Rhizobium sp, Azospirilum sp)
9. Using of high yielding variety of rice and soybean
10. Maintenance for water canal and stopper
11. Maintenance for pest management with bio-pesticide
12. Harvest and post harvest management
13. Facilitation of food crop market system

Cultivation Technology on The Different Farmer Type in Tidal Swamp

Description	Cultivation Technology			
	Local Farmer	Transmigration Farmer	Farmer with SSC Innovation	Farmer with SSC and Organic Farming (Next Time Planning)
Variety	Local (6 month)	High Yielding Variety (4 month)	High Yielding Variety (4 month)	High Yielding Variety (4 month)
Water Management	Flooded Culture	Flooded Culture	Saturated Soil Culture	Saturated Soil Culture
Ameliorant	Without	Without	Dolomit + Cow Dung + husk Ash	Straw Biomass or Soybean Biomass + Cow Dung
				+ Humicc Acid
Fertilizer	Without	N, P, K	N, P, K	Biofertilizer (Azospirilum sp, Micorrhyza sp) + Guano
Pesticide	Without	Herbicide, Insecticide, Fungycide	Herbicide, Insecticide, Fungycide	Biopesticide (clove oil 5 ml/l water)
Rice Productivity (ton/ha)	1.5-2.0	2.5-3.0	5-7	Prediction : 5-7



Collaboration System With Academician, Businessman, Government, and Community

- Academician :graduate student of IPB University give guidance of SOP (Standard of Operational Procedure). The graduate student stay in the field to guide from planting, maintenance, and harvesting
- Businessman : private company of FKS Multi Agro give financial capital to the farmer to buy seed, ameliorant, and fertilizer, and facilitate to market system
- Government : give the equipment (tractor, harvester,), and socialization SOP with Graduate Student by Field Information Official
- Community : The Farmer give modal of land and labor
- Profit : 75 % for farmer, and 25 % for private company

CONCLUSION

- 1) The reduction of shoot Fe content on SSC was higher on sensitive rice variety than tolerant rice variety on FC
- 2) The productivity of rice on SSC was higher than FC
- 3) Humic acid decreased of soil Fe and Al, and application of peat humic acid increased of rice productivity
- 4) The application of organic rice farming in tidal swamp can be done with : high yielding variety, SSC technology, ameliorant of rice biomass, peat humic acid, dung fertilizer, bio-fertilizer, and bio-pesticide
- 5) Collaboration with ABGC system will give beneficial to the Farmer and Private Company

ACKNOWLEDGEMENTS

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THANK YOU