LOWLAND RICE ENVIRONMENT AND POTENTAL IN WEST AFRICA

Jun-Ichi Sakagami

Japan International Research Center for Agricultural Sciences

1-1 Ohwashi, Tsukuba, Ibaraki, 305-8686, Japan

ABSTRACT

The lowland rice environment in West Africa is extremely complex. The potential for production of lowland rice is much higher than that for upland ecologies, presenting the possibility of cultivating two or more crops annually. Lowland rice therefore becomes a more economically valuable crop than upland rice. Although rice consumption in African countries has increased in recent years, the production rate is insufficient to meet demand. The volume of imported rice is increasing annually, which is having a detrimental effect on African countries' economies. To resolve these issues, rice production yields must be increased, either by expanding the production area or by improving the yield per unit of area. Realization of this goal is impeded primarily by the poor agricultural environment and unsophisticated agricultural technologies prevailing in Africa. Farmers account for 80% of the population in African countries and make up a larger proportion of those below the poverty line than in Asian countries. Therefore it is difficult for rice farmers to acquire adequate equipment and materials to produce rice rationally using best practices.

In lowland ecologies, rice plants often confront shortages and excesses of water, iron toxicity, weeds, diseases, and insects. The irrigated area is 20% of the total area of rice cultivation in West Africa. Most rice is planted in rainfed regions (Balasubramanian et al. 2007). Therefore, rice cultivation in West Africa is influenced strongly by precipitation or overflow from rivers. Upland rice is severely influenced by rainfall because of the lack of standing water. Yields of upland rice are very low (around 1 t ha^{-1}) compared with those of lowland rice cultivation (around 2 t ha^{-1}) (Norman and Otoo 2003). Rainfed lowlands therefore offer greater potential for raising rice production, and represent about 20–50 million hectares depending on the definition used. At present, only about 10–20% of this area is under cultivation (Africa Rice Center 2004), thereby offering great potential for rice farming expansion in lowland ecologies. Rainfed lowlands are of various types according to topographic characteristics such as coastal areas, river lines, and inland valleys in West Africa. Rainfed lowland, deepwater, and mangrove swamp ecosystems occupy over 33% of the rice cultivation area from Senegal to Sierra Leone in the Guinea gulf and Nigeria (Balasubramanian 2007). Deepwater ecosystems occupy more than 50% of rice-cultivated areas in Mali, Niger, and Chad.

A major limiting factor in rainfed lowlands is water control. Rainfed lowlands are classified as drought-prone, drought and submergence-prone, or submergence-prone areas. Drought-prone areas are constrained by a short rainy season. To adapt to such environments, rice cultivars must have short growth duration. Drought and submergence-prone ricelands are often affected by drought. However, rice cultivation areas are inundated by flooding water by heavy seasonal rains. To adapt to such an environment, drought-tolerance and submergence-tolerance are necessary. Areas prone to submergence by less than 50 cm are generally suitable for rice production; however rice cultivars must have high photosynthetic capacity for prolonged submergence. Deepwater rice—floating rice plants which can grow in more than 50 cm of water—must have shoot or internodal elongation capability.

KEYWORDS

Deepwater, Drought, Lowland, Rainfed, Submergence

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Trends of International Rice Research and Japanese Scientific Contribution - Support to GRiSP and CARD

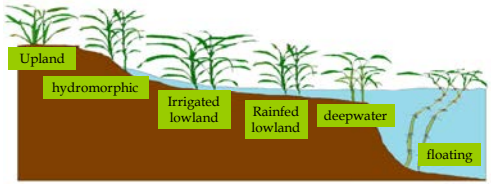
Outline

- Rice ecosystems in West Africa
- Limiting factors of lowland rice
- Water stresses in rainfed lowland
- Genetic by Environment interaction in rainfed lowland
- Development of rice cultivation technologies in flood-plains

Lowland vs Upland

Based on water regime, rice lands are classified as :

- **Upland**, with no standing water
- **Lowland** including irrigated and rainfed, with less than 50 cm of standing water
- **Deepwater** including floating, with more than 51 cm to 5-6 m of standing water



Classification of rice culture in West Africa

1 Upland
- Dryland
- Hydromorphic

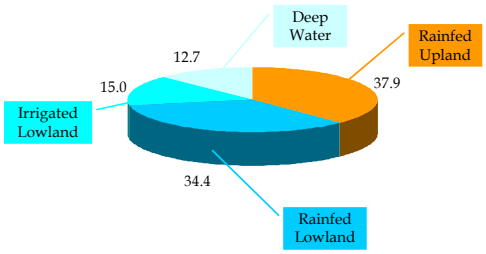
2 Irrigated

3 Inland swamp
- Nontoxic soil
- Toxic soil

4 Flooded
- River basin shallow
- River basin deep
- Boliland
- Mangrove

By Buddenhargen(1978)

Estimate of the percentage of rice crop area in West Africa



Data source: Jonne Rodenburg and Matty Demont, 2009

Irrigated lowland x Rainfed lowland

- Land is either prepared wet or dry but water is always held on the field by bunds.
- Irrigated rice can manage flood water.
- In rainfed lowland, the rice is not irrigated, the soil surface is flooded for at least part of the rice cycle.
- About 35% of the West Africa is grown as rainfed lowland and about 15% as irrigated lowland on rice cultivated area.
- Rice plants often confront shortages and excesses of water in rainfed lowland.

Water stresses in rice ecosystem

Major ecosystem	Sub ecosystem	Major constrains in water stress	Typical region
Upland	Mountain slop	Drought	Ivory Cost, Sierra Leone
	Plateau	Dorught	Ghana, Guinea
Lowland	Irrigated	Favorable	Mauritania, Niger
	Rainfed	Drought- and submergence-prone	Ngeria, Senegal
	Deepwater	Drought- and submergence-prone	Chad, Mali
	Mangeove swamp (Tideland)	Submergence	Gambia, Guinea-Bissau

Drought in rainfed lowland

Drought resistance:
Ability of plants to maintain functions at the same level as those under adequate soil moisture condition.

Drought Avoidance

Drought Escape | Drought Tolerance

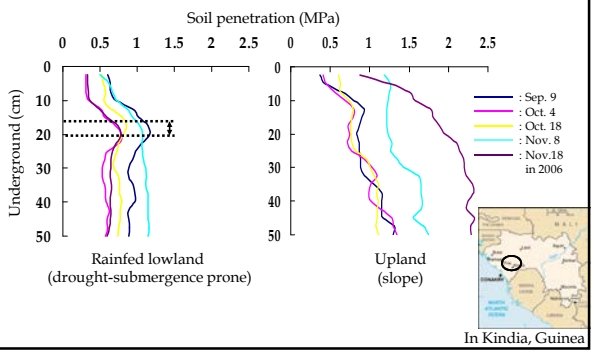
High capabilities of maintaining internal water

Quantity of the dry matter production

Strongly relates to yield abilities

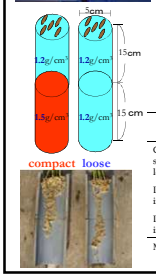
Development of deep root

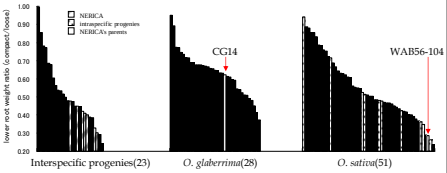
Soil hardpan in rainfed farm



In Kindia, Guinea

Root development under compacted soil under rainfed condition





	Interspecific progenies		*O. glaberrima*		*O. sativa*	
Compacted soil/Loose soil in lower layer	0.479±0.027	b	0.599±0.022	a	0.516±0.020	b
Lower layer/ All layer in Loose soil	0.307±0.013	b	0.366±0.011	a	0.305±0.007	b
Lower layer/ All layer in Compacted soil	0.150±0.009	b	0.223±0.009	a	0.159±0.006	b

Mean values followed by the same letters are not significantly different at the 0.05 level by Fisher's PLSD.

(Nakamura et al. 2006)

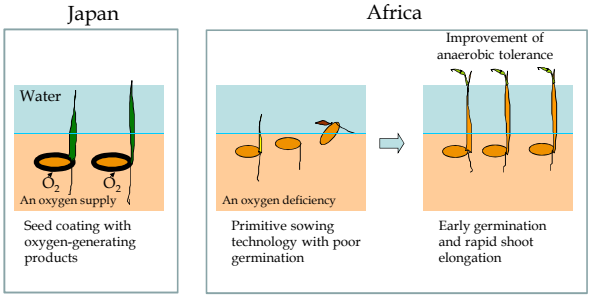
Flooding in lowland and deepwater


Flash floods at seedling stage in Guinea

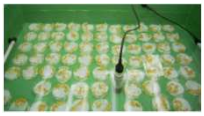

Heading of deep-water rice in Niger

Type	Tolerance	Escape	
Rice growing environment	Flash Floods less than 2 weeks	Short to long-term floods with shallow water	Long-term floods with deep water
Eco-physiological mechanism for survival strategy	Slowing of ethylen-promoted leaf elongation to conserve energy	Rapid leaf elongation by LOES (Low Oxgen Escape Syndrome) to restore contact between leaves	Rapid internodal or stem elongation to resume anaerobic metabolism and photosynthesis
Conservation of carbohydrate	High	Low	Low
Rice ecotype	Quiscence rice	Shoot elongating rice	Deepwater rice, floating rice

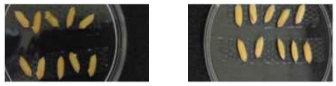
Improvement of submergence "Tolerance" for direct seeding



Anaerobic germination



Aerobic LAC23 Anaerobic

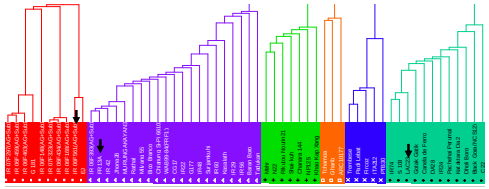


FR13A

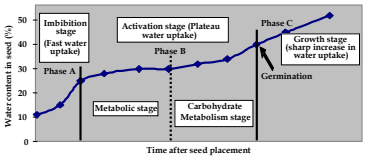
IR06F561

- 60 cultivars
- Treatment: 120h
- Air and water temp.: 20°C
- Submergence(Anaerobic) :10cm depth water
  Control(Aerobic) :0.1cm depth water

Cluster analysis of anaerobic germination with water absorption

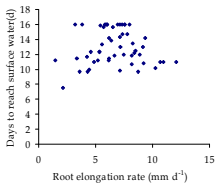


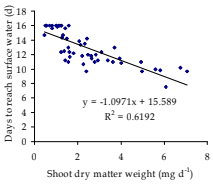
(EL-Hendawy et al. 2011)



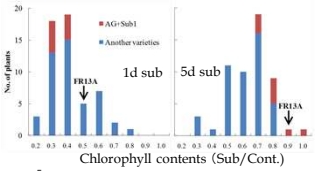
A complex mechanism on anaerobic germination and submergence

- 60 cultivars
- Treatment: 16d
- Air and water temp.: 28°C
- Submergence(Anaerobic) :10cm depth water
  Control(Aerobic) :0.1cm depth water

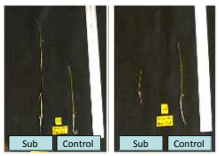




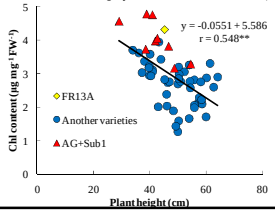
Effects of submergence on chlorophyll contents in the leaves



Chlorophyll contents (Sub/Cont.)

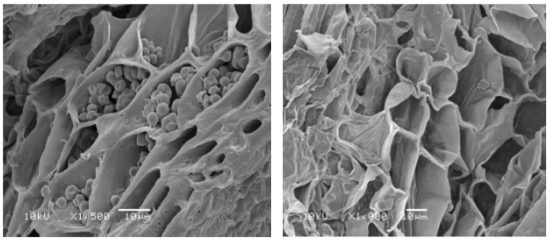


IR06F459 IR06F393



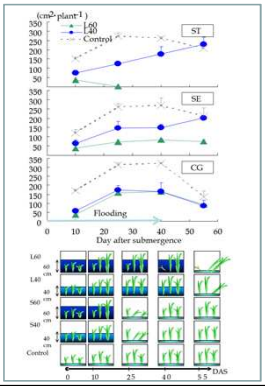
Starch grain of AG+Sub1

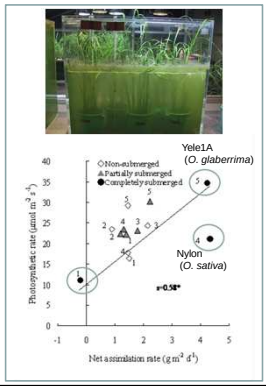
AG+Sub1 line Susceptible genotype to submergence



Part of 3rd leaf of submerged plant at 16d submergence

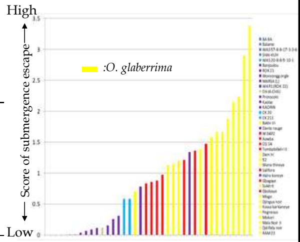
Submergence "Escape" in the pots





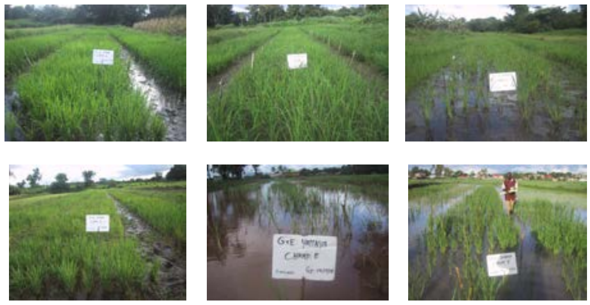
Submergence escape in the fields

Genotype	Non-submergence: Shoot elongation ($cm\ d^{-1}$)	Non-submergence: Shoot biomass increase ($g\ d^{-1}$)	Complete-submergence: Shoot elongation ($cm\ d^{-1}$)	Complete-submergence: Shoot biomass increase ($g\ d^{-1}$)
O. sativa L.				
BA8A	1.38	0.41	1.78	0.04
Balante	0.94	0.34	1.17	0.02
Banjoulou	0.95	0.32	1.23	0.02
Cinquant-deux	1.25	0.55	2.12	0.16
CK20	1.45	0.37	1.58	0.03
CK211	1.32	0.40	1.82	0.04
CK4	1.31	0.33	1.49	0.03
CK41	1.52	0.41	1.71	0.04
Danta rouge	1.54	0.48	2.43	0.07
EH-IA-CHIU	1.16	0.42	1.39	0.02
FR13A*	1.19	0.38	Death	Death
Gallale Blanc	0.65	0.24	1.89	0.12
Haïra koreye	1.43	0.45	2.15	0.05
IR49830-7-1-2-2	0.97	0.40	1.40	0.02
IR62293-2B-18-2-2-1-3-2-3	1.59	0.47	1.61	0.04
IR67520-B-14-1-3-2-2*	1.01	0.35	Death	Death
IR70027-8-2-2-3-2*	1.50	0.46	Death	Death
IR71700-247-1-1-2	1.19	0.42	1.65	0.02
IR73018-21-2-B-2-B*	0.95	0.35	Death	Death
IR73020-19-2-B-3-2B*	1.32	0.29	Death	Death
Kaolac	1.23	0.36	1.60	0.03
Kaorin	0.99	0.42	1.55	0.02
Kōticondre	1.03	0.49	1.42	0.03
Marsal	1.09	0.45	1.72	0.05
N 22	1.26	0.43	1.69	0.05
N'ckrome	0.97	0.46	1.70	0.04
NIK 1A	1.17	0.53	1.30	0.02
Nylon	1.18	0.32	1.58	0.02
Protocolo	1.47	0.41	2.10	0.04
Reymont	1.03	0.22	1.21	0.01
ROK21	1.22	0.20	1.60	0.03
SHAI-KUH	1.08	0.38	1.29	0.03
Vandana	1.46	0.41	1.65	0.03
WAR1(ROK22)	1.26	0.32	1.58	0.03
Wonsongg orgle	0.88	0.26	1.53	0.02
O. glaberrima Steud.				
Aawba	1.14	0.32	1.84	0.08
Bakin Iri	1.06	0.51	1.87	0.12
CG14	0.97	0.40	1.67	0.07
Dam Iri	1.25	0.57	2.02	0.16
Dembou bourawana blanc	0.75	0.18	1.99	0.09
Djéifata noir	0.96	0.36	2.25	0.11
Djingua noir	0.76	0.35	1.91	0.14
Douboutou II	0.91	0.36	1.89	0.07
Gbagaye	1.10	0.34	1.95	0.06
Gbobaye	1.13	0.46	1.87	0.06
Kossa barkaneye	1.26	0.44	1.96	0.11
Mala Noir II	0.99	0.31	2.08	0.13
Mala Noir III	0.89	0.32	2.24	0.16
Mogo	1.28	0.47	2.24	0.14
Mokori	1.05	0.36	2.25	0.10
Pegnesso	0.71	0.23	2.06	0.07
RAM 23	0.70	0.44	2.13	0.14
Salifore	1.39	0.49	1.80	0.08
Saligbeli	1.23	0.38	2.00	0.10
Salikutaforé	1.14	0.30	1.68	0.04
Samandényi	1.08	0.20	1.62	0.07
Sukéré	1.42	0.42	1.90	0.15
Tierka banc	0.91	0.31	2.06	0.13
Tombobökéri II	1.25	0.30	1.95	0.11
W0492	1.87	0.49	1.87	0.06
Wana thireye	1.25	0.42	2.06	0.13
Yélé 1A	0.63	0.32	1.96	0.17
Average(±SE)				
O. sativa L.(n=30)	1.20±0.04	0.39±0.02	1.63±0.05	0.04±0.01
O. glaberrima Steud.(n=27)	1.08±0.05	0.37±0.02	1.97±0.03	0.10±0.01
O. sativa x *O. glaberrima*	NS	NS	**	**



Genetic by Environment interaction in rainfed lowland (2007-2011)

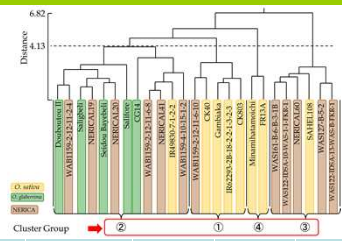
Experimental site:Rainfed lowland of submergence-drought prone area in Guinea



Cultivar and yield in 2008

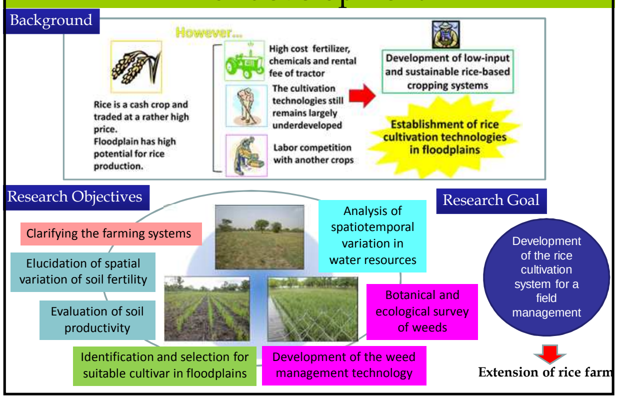
Genotype	Experimental Site: A	B	C	D	Average	Max.	Min.	CV(%)
***O. sativa* L.**								
CK40	0.43	0.23	0.27	0.13	0.27	0.43	0.13	46
CK803	0.36	0.28	0.14	0.23	0.25	0.36	0.14	35
FR13A	0.15	0.15	0.07	0.10	0.12	0.15	0.07	35
Gambiaka	0.34	0.27	0.21	0.22	0.26	0.34	0.21	23
IR49830-7-1-2-2	0.30	0.24	0.26	0.02	0.21	0.30	0.02	60
IR62293-2B-18-2-2-1-3-2-3	0.31	0.26	0.17	0.12	0.21	0.31	0.12	39
Minamihatamoichi	0.12	0.15	0.07	0.07	0.10	0.15	0.07	38
SAHEL108	0.21	0.16	0.09	0.12	0.15	0.21	0.09	33
***O. glaberrima* Steud**								
CG14	0.28	0.29	0.41	0.22	0.30	0.41	0.22	26
Douboutou II	0.35	0.25	0.31	0.26	0.29	0.35	0.25	16
Salifore	0.38	0.30	0.12	0.27	0.27	0.38	0.12	40
Saligbeli	0.36	0.25	0.19	0.16	0.24	0.36	0.16	36
Seidou Bayebeli	0.32	0.18	0.19	0.18	0.22	0.32	0.18	33
NERICA								
NERICAL19	0.33	0.20	0.20	0.11	0.21	0.33	0.11	43
NERICAL20	0.24	0.21	0.18	0.22	0.21	0.24	0.18	10
NERICAL41	0.25	0.26	0.21	0.14	0.21	0.26	0.14	25
NERICAL60	0.29	0.25	0.15	0.09	0.19	0.29	0.09	47
WAB1159-2-12-11-2-4	0.33	0.25	0.21	0.31	0.27	0.33	0.21	20
WAB1159-2-12-11-6-10	0.40	0.17	0.34	0.24	0.29	0.40	0.17	35
WAB1159-2-12-11-6-8	0.29	0.25	0.24	0.10	0.22	0.29	0.10	37
WAB1159-4-10-15-1-2	0.20	0.17	0.28	0.10	0.19	0.28	0.10	41
WAS122-IDSA-10-WAS-1-1-FKR-1	0.28	0.15	0.21	0.08	0.18	0.28	0.08	48
WAS122-IDSA-13-WAS-B-FKR-1	0.19	0.17	0.10	0.12	0.15	0.19	0.10	28
WAS127-B-5-2	0.15	0.18	0.09	0.09	0.13	0.18	0.09	35
WAS161-B-6-B-3-1B	0.29	0.18	0.21	0.14	0.21	0.29	0.14	32
Average								
O. sativa	0.28	0.22	0.16	0.13	0.20	0.43	0.02	49
O. glaberrima	0.34	0.25	0.24	0.22	0.26	0.41	0.12	30
NERICA	0.27	0.20	0.20	0.15	0.20	0.40	0.08	37
Average	0.29	0.22	0.20	0.15	0.21	0.43	0.02	40

Cluster analysis



Cluster group	Number of panicle($hill^{-1}$)	Number of spikelet ($panicle^{-1}$)	1000 grains	Yield($kg\ m^{-2}$)	
①	8.6	103	29.2	0.26	⇦ SNT
②	11.7	77	26.1	0.24	⇦ Intermed.
③	13.8	58	23.7	0.17	⇦ PNT
④	8.4	60	27.8	0.10	

Sustainable rice system in flood-plains for development



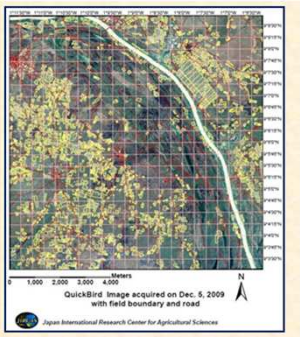
Site specific reseach

	Zaw	Yipergu
Location	40Km SW of Tamale	15Km W of Tamale
Water source	Flood water	Rain & ground waters
Rice cropping	Extensive with primitive technologies	Intensive & mechanization
Problem	Labor competition	Low profit due to high inputs

Characterizations of floodplains by satellite

Land use map of Zaw village

Pan- sharpening
⇩
Image interpretation
⇩
Screen digitizing
⇩
Overlay / Impose



Household investigation

Interview all families in Zaw village

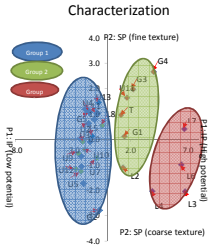
- *Analysis of farm management and economic efficiency*
- *Elucidation of limiting factors for farmers*

Zaw village	
Total of Households	42
Total of people	290
Total of farmers	120
Total of agri. area	180ha
Average of farmer's family members	6.9
Average of agri. workers in a family	2.8
Average of cropping area	4.4 ha (0 – 14ha)

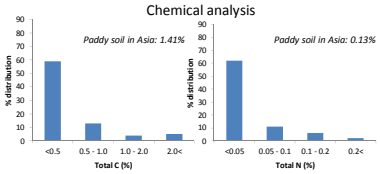
67% of non-rice cultivator is interested in rice cultivation.
Initial capital and tractor restrict initiation of rice cultivation.

Evaluation and mapping of soil fertility

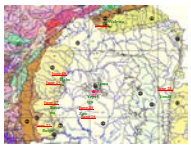
Characterization



Chemical analysis



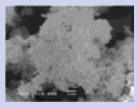
Evaluation of natural resource for application in cropping system



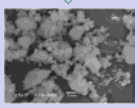
Rock sampling in Ghana

Analysis of :
- Crystalline form of apatite (phosphate rock)
- Characteristics of clay mineral in soil

Availability of local resources for making fertilizer



Original crystalline form



Solid after 5 hours frictionally-fracturing

Collection and classification of weeds

Borreria filifolia

Cleome viscosa

120 species were identified in lowland Savanna

Database "Plants in lowland savanna in West Africa"
http://www.jircas.affrc.go.jp/project/Ghana/home.html

Selection of cultivar

O. sativa
O. glaberirma
} 298 cultivars

Physiological examination in laboratory

Experimentation in submergence field (SARI)

Evaluate tolerance to flood-plains environment

Conclusions

1. There is a large lowland area in particular river basin where is not used for rice cultivation in West Africa.
2. The environment of rainfed lowland and deep-water is stable productivity for reason of soil fertility, water availability and sustainability.
3. The introducing rice cultivation is required that several adequate cultivars are developed for flood-plains environment.

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