ADVANCES IN RICE BREEDING FOR AFRICA

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ABSTRACT

AfricaRice is well known for its NERICA varieties, which has become a household name in Africa. About 700,000 ha of rice land is currently grown under NERICA varieties in both upland and lowland conditions (NERICA-L varieties). AfricaRice and partners from national and international research organizations are continuously striving to develop new materials that will be worthy successors of these NERICA varieties and other improved varieties developed by AfricaRice and partners over the last decades, such as the WAB and Sahel series.

The NERICAs were developed from a very narrow genetic resource base. The genetic resources unit in AfricaRice carries more than 20,000 collections of *Oryza* accessions, including African domestic accessions of *O. sativa, O. glaberrima* and *O. barthii.* Characterization of core collections of these accessions is ongoing for different key traits (drought, salinity, tolerance to P-deficiency, flood tolerance, disease resistance) with a number of advanced research institutions across the globe.

Recent evaluation of landraces of *O. sativa* as well as *O. glaberrima* revealed several important traits. For rice yellow mottle virus (RYMV), one of the most devastating diseases in Africa, several accessions of *O.glaberrima* showed resistance to strains of the virus, and markers associated for each type of resistance have been identified. Salt tolerance is one of the essential traits for rice growing in coastal and even inland areas in many African countries. Landraces collected in salt-affected fields, *O. glaberrima* and lowland NERICA varieties were evaluated for salt tolerance under both field and controlled conditions, resulting in the identification of a number of tolerant entries, among which 8 landraces, 4 *O. glaberrima* and 4 lowland NERICAs. Preliminary molecular characterization indicates that for the majority of these materials tolerance is governed by a locus different from *saltol*, which has been widely used in marker-assisted selection .

AfricaRice uses MAS in a number of breeding programs where appropriate markers have been validated and are routinely available. In the breeding of RYMV resistant varieties, markers associated with *rymv 1-2*, which has been identified in collaboration with IRD, France were used. Resistant BC_3F_5 lines are under evaluation for agronomic traits at multiple locations in Africa. Moreover, to make the resistance more durable in Africa, markers for *rymv2* are being introduced to breeding lines carrying *rymv1-2*. For rice blast, the most destructive fungal disease in Africa, field resistant genes, *Pb1* and *pi21*, both of which were kindly provided by NIAS, Japan, are being introduced for mega-varieties in upland and irrigated environments. Furthermore, a locus resistant to salt, *saltol*, and a resistant gene to submergence, *sub1*, are under introgression into lowland varieties in Africa. MAS will also be used for introducing cold and Fe toxicity tolerance, upon identification of appropriate markers.

Breeding programs at AfricaRice, IRRI, CIAT and NARS continuously produce promising breeding lines. In 2010, the Africa Rice Breeding Task Force was launched to facilitate a more systematic evaluation of many promising breeding lines from various institutions, under multiple environmental conditions, and with the same protocol for evaluation. The Task Force involves breeders from 28 African countries and covers four mega-environments: the rainfed lowland, rainfed upland, irrigated and high elevation environments and consists of three phases of evaluation trials; regional, national and multi-locational trials including participatory varietal selection (PVS). Task Force activities are facilitated by breeders from AfricaRice and IRRI based in Africa, which have been assigned responsibilities for the various mega-environments. During the 2011 wet season, about 500 lines were under evaluation at more than 20 sites across Africa. The breeding

lines selected at the last phase of this evaluation process will be recommended to target countries or regions. AfricaRice processes all data centrally using IRIS, allowing for a systematic G x E approach to varietal evaluation across Africa.

AfricaRice estabished a hybrid-rice program in late 2009 at its research station in Senegal through the recruitment of an experienced Egyptian hybrid rice breeder, who works in close collaboration with breeders from IRRI and China. Restorer lines have been identified among African varieties and male sterility has been introduced into a number of varieties.

The Global Rice Science Partnership (GRiSP) led globally by IRRI and in Africa by AfricaRice will accelerate varietal development in Africa by mobilizing global expertise for well-defined pre-breeding and breeding products of relevance to Africa's growth environments and consumer preferences. GRiSP has also launched a global phenotyping network with unified protocols for important traits (such as drought), which is expected to be of great benefit to rice breeding activities in Africa.

KEYWORDS
Rice Breeding, Abiotic Stress Tolerance, Disease Resistance, Multi-sites multi-year evaluation trials, Africa

Advances in Rice Breeding for Africa

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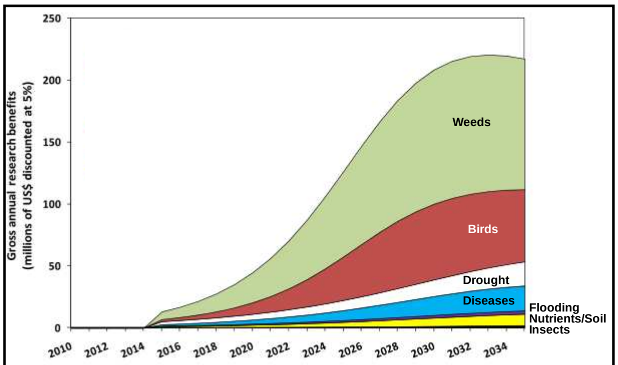


Attributable gross annual research benefits expected over time from the adoption of new "best-bet" technologies to reduce yield and efficiency gaps in Sub-Saharan Africa

Rice Breeding in AfricaRice

- **Target Environment:**
  - Rainfed Lowland
  - Upland
  - Irrigated
  - High Elevation

- **Target Trait:**

・Abiotic stress:	Drought, Submergence, Cold, Heat Fe-toxicity, P-deficiency, Salinity
・Biotic stress:	Blast, RYMV, BLB, AfRGM
・Grain Quality:	Appearance

Flow of Development of New Varieties

Germplasm	Pre-Breeding	Breeding	Evaluation		New Variety
● Conservation ● Trait identification ● Data management	● Trait/Gene identification ● Marker development	● Trait incorporation ● Marker assisted selection ● Conventional selection ● Line Development	● Multi-site, multi-year, evaluation ● Key site, NARES ● PVS ● INGER	• Variety Release System • Seed Production System	Each Region, Country

GRiSP Theme 1 → (Germplasm to Breeding)

GRiSP Theme 2 → (Breeding to Variety/Seed System)

Germplasm conservation, characterization

- **Total accession at GRU**: about 20,000
- **Germplasm characterization**
  - *O. glaberrima, O. barthii* — Agro-morphological traits
  - Landrace — Agro-morphological traits
  - *O. glaberrima, O. barthii* — Major disease resistance (Systematic evaluation, initiated)



New Germplasm Tolerant to Salinity

1. 8 Salt tolerant landraces out of 188
   Screening: Hydroponic and field
2. Lowland NERICA
   Nerica-L9, -L23, -L24 , L27
3. *O. glaberrima* (104 accessions)
   TOG6224, TOG7230,
   RAM26, RAM121

Variety	Tolerance to Salinity	Country of Origin
Jarmissa	5	Gambia
Many Fingo	3	Gambia
Camaro	5	Gambia
Condeh Mano	5	Gambia
Madina Koyo	5	Senegal
Gold Coast Fingo	3	Gambia
Nafisatu	5	Gambia
FL 478 (Tolerant Ck)	4	IRRI
IR 29 (Sensitive Ck)	9	IRRI

Breeding for Cold Tolerance

Is Cold Tolerance Necessary in Africa?

1. Sahel zone of West Africa
   Below 12 ℃ during November to March.
2. High altitudes areas (more than 1000 m).
   Madagascar : more than 120,000 ha affected
   Other East African countries

Breeding for cold tolerance

1. **Screening method**
   In Screenhouse (Air temp 17C, water temp 10C)
   Hot Spot Igurusi, Uyole (Tanzania)
   Ndiaye, Fanaya (Sengal)
   Kogoni (Mali)
2. **Breeding status**
   Tolerant Donor: Kunming, M202
   Recipient: X-Jigna, WAB189, FOFIFA37337
   Backcross BC2F2 population

Breeding for RYMV Resistance

Epidemic of RYMV in Burkina Faso
(Photo by Sokei)

Resistant Genes to RYMV

- **RYMV 1** (Multiple allele: only 1- 2 amino acid substitution) Chromosome 4
  - ***rymv 1-2*** *O. sativa* Gigante, Bekarosaka
  - *rymv 1-3* *O. glaberrima* Tog5681
  - *rymv 1-4* *O. glaberrima* Tog5672
  - *rymv 1-5* *O. glaberrima* Tog5674
- **RYMV 2** *O. glaberrima* Acc104589 Chromosome 1

MAS Scheme for RYMV

Recipient x Gigante
↓
F1 x Gigante
↓
BC1 x Gigante
↓ ← MAS *(rymv 1-2)*
BC2 x Gigante
↓ ← MAS *(rymv 1-2)*
BC3 x
↓ ← MAS (F, B whole genome)
BC3F3
↓
Phenotyping
- Field (Mali, Guinea)
- Screenhouse

Select: NIL 2, NIL 54, NIL 130, NIL 16 (BC3F4)

Recipient Variety
- Sahelika
- IR64
- IR47
- FKR28

Marker
Allele specific marker for *rymv 1-2*

Field Evaluation in Cotonou

May 2011

Gigante

IR64

NIL130: IR64 + rymv 1-2

Resistance confirmed also by;

- Evaluation at hotspots in Nigeria (2010)
- Artificial inoculation with the virus

Durable Resistance to RYMV

- **Strategy for durable Resistance**

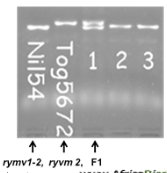
  Combine *rymv 1-2* and *rymv 2*

  Markers for *rymv* 2 identified by IRD

- **Cross combination**

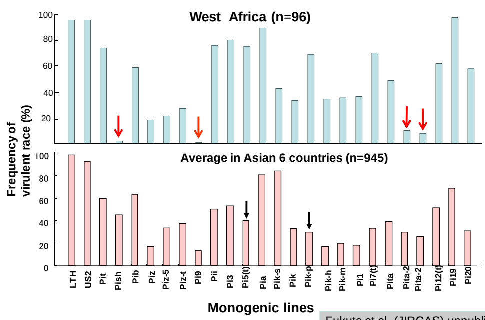
  IR64 NIL x iBridge :
  (rymv 1-2) *O.glaberrima* 104589 *(rymv2)*

Current Generation:
F1



Durable Resistance to Blast

Reaction of West African blast isolates to monogenic lines



Fukuta et al. (JIRCAS) unpublished

Strategy for Durable Resistance to Blast

Use of field resistant genes by MAS

- *Pb1* confirmed by breeding in Japan
- *pi21* confirmed by MAS in Japan

Status of MAS

- Marker information: *Pb1*, *pi21*
  Delivered by NIAS (2010 Dec)
- Resistant Donor: Modan *(Pb1)*, Owari-hata-mochi *(pi21)*
  Delivered by Genebank NIAS (2011 Jan)
- Recipient Varieties:
  Irrigated: Sahel 108, NERICA L-19, Kogoni 90-2
  Upland: NERICA 1, NERICA 4, FKR 43
- Cross: F1 for irrigated

Status of MAS

Trait	QTL	Donor	Recipient	Generation
RYMV1	*rymv 1-2*	Gigante	IR 64	BC_3F_6
RYMV2 + RYMV1	*rymv 2*	TOG 104589	IR 64 + rymv1-2	F_1
Blast Field R	*Pb1*	MODAN	Sahel 108	BC_2F_1
Blast Field R	*pi21*	Owari H M	Sahel 108	F_1
Salt tolerance	*saltol*	FL478	Rassi	BC_4F_2
Submergence tolerance	*sub1*	Swarna sub1	WITA 4	BC_2F_1

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Hybrid Rice for Africa

Evaluation of Chinese Hybrid and Inbred in Africa

Inbred 77 lines
Hybrid 276 lines
(from China)

Evaluation in 8 counties in Africa **2009**

Evaluation in 8 counties in Africa **2010**

Promising Lines
Inbred 30
Hybrid 29

PVS Trials in Wet Season 2011

PVS Trials in WS2011

Country	Hybrid	Inbred
Mali	6	5
Senegal	7	5
Nigeria	8	5
Uganda	7	5
Rwanda	7	5
Tanzania	7	5
Liberia	5	5
Mozambique	8	5

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Hybrid Rice Breeding at AfricaRice

- Identification of Restore Line;
  IR31785, NERICA L20, L30, 10, L32
  RASTA, SAHEL 108, SAHEL 134
- Development of Male Sterile Line (WA)
  Parents: IR58025, IR68886A, IR69625 A
  Backcrossed to NERICA L14, L36, L50 (BC_2F_1)
- Combining ability
- Seed Production


Seed Production


Hybrid line ARS104H

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Africa Rice Breeding Task Force

Lines developed by ongoing Projects STRASA, GSR, GCP, Japan Rice Breeding etc

Varieties developed by NARES, IRRI, CIAT

Breeding Task Force

- Regional Trials — 500 lines /year
- National Trials — 100 lines /year
- Rice Garden — 50 lines /year
- Multi-location Trial | Baby Trial
- Multi-location Trial | Baby Trial — 5 Nominated lines /year

Recommendation to Target Country

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Key Components in Breeding Task Force

1. Multi-location, Multi-year evaluation
   ⇨ Reliability of selection of breeding lines
2. Same experimental design and traits measured in all sites
   ⇨ Direct comparison of all data acquired
3. Centralized data analysis
   ⇨ Selection supported by data, record of selection process
4. Involvement of NARS breeders in all evaluation phase
   ⇨ Exposure of promising breeding lines to NARS at early stage of evaluation
   ⇨ Shorten time of variety release, possibly

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Regional and National Trials 2011

Trial	Ecology	Sites	Lines
Regional	Lowland	4	278
	Irrigated	6	278
	Upland	3	216
National	Lowland	13	100
	Upland	3	216

Trials	Traits	Number	Organization
Regional	Salt tolerance	1	AfricaRice
	Fe tox tolerance	7	AfricaRice, SLARI
	AfRGM resistance	3	AfricaRice, NCRI
	Blast resistance	3	AfricaRice, CIAT
	Grain Quality	16	AfricaRice, Tanzania
National	Fe tox tolerance	6	AfricaRice, IER
	AfGM resistance	9	AfricaRice, NCRI
	RYMV	8	AfricaRice, IRRI, IER
	Blast	8	AfricaRice
	Grain Quality	16	AfricaRice, IER

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Sites for Trials in Breeding Task Force 2011

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Dissemination of Varieties

- NERICA (Upland)
  - Popular varieties: NERICA 1 (15) NERICA 4 (17)
  - 22 countries
- NERICA L (Lowland)
  - Popular varieties: NERICA L19 (8), NERICA L20 (4)
  - 9 countries

Source: NERICA: origin, nomenclature and identification characteristics. May 2007
Rice Statistics Database 2009

Estimated Acreage of NERICA:
ca. 700,000 ha (Statistics + Estimation)
National statistics (Rice Statistics Project)

Mali: **90,000 ha** (2011)
Nigeria: **243,000 ha** (2009)
Guinea: **140,000 ha** (2009)
Gambia: **60,000 ha** (2010)

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Varieties Released (2007 – 2011) in Africa

	Country	Number	Year	Varieties
Upland	Senegal	2	2009	WAB56-50, ITA
	Tanzania	1	2009	WAB 56-104
	Sudan	4	2010	WAB450--. Interspecific
	Kenya	5	2009	NERICA 1, 4, 10, 11
	Uganda	2	2007	NERICA 1, 10
	Ethiopia	4	2009-10	NERICA 6, 14, 15 FOFIFA3737
Lowland	Benin	1	2009	FKR19
	Liberia	1	2009	FKR19
	Togo	2	2009	Orylux 1, 5
	Gabon	1	2010	WAB638, derivative aromatic
	Niger	2	2007	NERICA L39, L49
Irrigated	Senegal	16	2007-9	Sahel 159, 134, 208, 209, 177, 217, 328
	Niger	2	2007	Sahel 208, WAS4--
	Mali	3	2011	Sahel 177, WAS64--, WAS49
	Ghana	3	2009	TOX3737, 3233, Jasmin85
	Rwanda	11	2010	IR lines, WAB, WITA4

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Flow of Development of New Varieties

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1.1. Ex situ conservation, dissemination of rice germplasm

2.1. Breeding informatics and multi-environment testing

2.2. Improved donors and genes/QTLs conferring valuable traits

2.3. Rice varieties tolerant to abiotic stresses

2.4. Improved rice varieties for intensive production systems

1.2. Characterizing genetic diversity, creating novel gene pools

2.5. Hybrid rice for the public/private sectors

1.3. Genes, allelic diversity conferring stress tolerance/ enhanced nutrition

2.6. Healthier rice varieties

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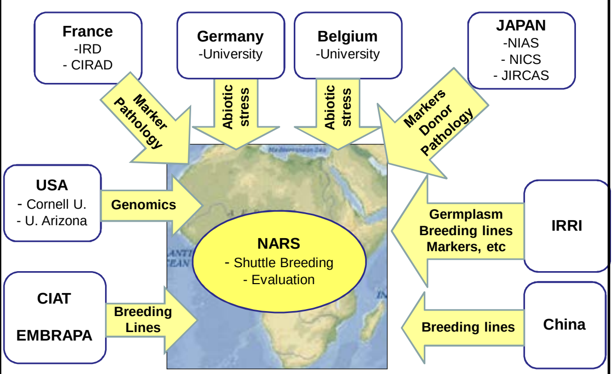
Strong Collaboration under GRiSP Theme 1, 2



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