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Africa Rice Center (WARDA)



NERICA[®]: the New Rice for Africa – a Compendium



Editors

EA Somado, RG Guei and SO Keya

2008 edition



About Africa Rice Center (WARDA)

Africa Rice Center (WARDA) is an autonomous intergovernmental research association of African member states and also one of the 15 international agricultural research Centers supported by the Consultative Group on International Agricultural Research (CGIAR).

WARDA's mission is to contribute to poverty alleviation and food security in sub-Saharan Africa (SSA) through research, development and partnership activities aimed at increasing the productivity and profitability of the rice sector in ways that ensure the sustainability of the farming environment.

WARDA hosts the African Rice Initiative (ARI), the Rice Research and Development Network for West and Central Africa (ROCARIZ), the International Network for Genetic Evaluation of Rice in Africa (INGER-Africa) and the Inland Valley Consortium (IVC). It also supports the Coordination Unit of the Eastern and Central African Rice Research Network (ECARRN), based in Tanzania.

WARDA has its headquarters in Cotonou, Benin and regional research stations near Saint-Louis, Senegal and at the International Institute for Tropical Agriculture (IITA) in Ibadan, Nigeria. WARDA's main research center is in Côte d'Ivoire but most scientists and researchers are temporarily located in Cotonou.

For more information, visit www.warda.org

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Citation

Africa Rice Center (WARDA)/FAO/SAA. 2008. NERICA®: the New Rice for Africa – a Compendium. EA Somado, RG Guei and SO Keya (eds.). Cotonou, Benin: Africa Rice Center (WARDA); Rome, Italy: FAO; Tokyo, Japan: Sasakawa Africa Association. 210 pp.

ISBN

92 9113 3167 English print

92 9113 3175 English PDF

Printing

Pragati Offset Pvt Ltd, Hyderabad, India

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PREFACE

This publication builds on the work of many individuals within and outside the Africa Rice Center (WARDA). Our main partners in this effort are the chapter authors who participated in the research reported here. This document was made possible by the contributors only because of their willingness to provide, sometimes at short notice, the required information. We express our grateful thanks and appreciation to them all, as well as to the many unnamed technical assistants and support staff.

This document would not have been feasible without the scientific and financial support from the Africa Rice Center (WARDA), the United Nations Food and Agriculture Organization (FAO) and the Sasakawa Africa Association (SAA), which jointly agreed to sponsor the preparation of this compendium. To them, and in particular to Dr Shellemiah O. Keya (WARDA), Dr Nguu Nguyen (FAO) and Dr Tareke Berhe, (Sasakawa Africa Association (SAA) we pay our special tribute for their foresight, interest and support throughout the preparation of this publication. Their interest and enthusiasm, and their inputs were always a source of stimulation and satisfaction. They deserve our special thanks.

The first draft of the document was reviewed and discussed by the WARDA's Editorial and Publication Review panel led by Dr Shellemiah O. Keya as well as by FAO's experts, including Dr Martinez Arturo (AGPS) and Dr Larinde Michael (AGPS). We also received invaluable feedback from Dr Tareke Berhe of Sasakawa Africa Association (SAA). These various inputs helped rewrite part of the Compendium. We wish to acknowledge the helpful review comments received from them.

Finally, we wish to thank Dr Inoussa Akintayo, Coordinator of the African Rice Initiative (ARI), for his assistance in collating the material.

The editors

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FOREWORD

The New Rice for Africa (NERICA) has been spreading rapidly in sub-Saharan Africa (SSA) since the first seed of these high yielding rice varieties was introduced in 1996. In 2006, a conservative estimate of area grown to NERICA varieties in SSA was about 200,000 hectares. Further spread is hampered by a lack of readily available scientific literature on the nutritional characteristics as well as the recommended production practices. Even the published material that exists has been rather scattered and sometimes anecdotal, thereby reducing its value to researchers, extension staff, farmers and consumers.

This compendium brings together the results of scientific research on the NERICA varieties, ranging from the choice of land to planting, integrated crop and pest management, harvest and post-harvest operations, agro-processing technologies and NERICA nutritional quality, and adoption impact on rice farmers' livelihoods.

Further contributions to the knowledge base on NERICA are welcomed and their channeling encouraged through the African Rice Initiative (ARI), which is hosted by WARDA.

On behalf of WARDA's Board and Management, I wish to express our appreciation to the United Nations Food and Agriculture Organization (FAO), the African Development Bank (ADB) and Sasakawa Africa Association (SAA) for their financial support for the compilation of this compendium.



Dr Papa A. Seck
Director General
Africa Rice Center (WARDA)

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OVERVIEW: RICE IN AFRICA

Contributors: Eklou A. Somado, Robert G. Guei and N. Nguyen

Unit 1 – The importance of rice in Africa

Africa has become a big player in international rice markets, accounting for 32% of global imports in 2006, at a record level of 9 million tonnes that year. Africa's emergence as a big rice importer is explained by the fact that during the last decade rice has become the most rapidly growing food source in sub-Saharan Africa (Sohl, 2005). Indeed, due to population growth (4% per annum), rising incomes and a shift in consumer preferences in favor of rice, especially in urban areas (Balasubramanian *et al.*, 2007), the relative growth in demand for rice is faster in this region than anywhere in the world (WARDA, 2005). This is occurring throughout the sub-regions of sub-Saharan Africa (SSA).

In recent years (2001–2005), rice production has been expanding at the rate of 6% per annum, with 70% of the production increase due mainly to land expansion and only 30% being attributed to an increase in productivity (Fagade, 2000; Falusi, 1997; Africa Rice Center, 2007). Much of the expansion has been in the rainfed systems, particularly the two major ecosystems that make up 78% of rice land in West and Central Africa (WCA): the upland and rainfed lowland systems (Dingkuhn *et al.*, 1997). Nonetheless, demand for rice in WCA has far outstripped the local production (Africa Rice Center, 2007).

According to OSIRIZ (¹CIRAD's Observatory of International Rice Statistics), Africa cultivated about 9 million hectares of rice in 2006 and production, which surpassed 20 million tonnes for the first time, is expected to increase by 7% per year in future. In West Africa, where the rice sector is by far the most important in SSA, the situation is particularly critical. Despite the upward trends in international and

¹CIRAD: Centre de coopération Internationale en Recherche Agronomique pour le Développement (FRANCE)

domestic rice prices, domestic rice consumption is increasing at a rate of 8% per annum, surpassing domestic rice production growth rates of 6% per annum. The production-consumption gap in this region is being filled by imports, valued at over US\$ 1.4 billion per year. The share of imports in consumption rose from an average of 43% from 1991 to 2000, to an average 57% by 2002–2004 (WARDA, *Rice Trends in Sub-Saharan Africa*, Third Edition, Cotonou, 2005, p. 31 and FAOStat; IRRI, *Rice Almanac*, 3rd Edition, Los Banos, 2002, p. 79).

The Food and Agriculture Organization of the United Nations (FAO) estimated in 2006 that current rice imports into the West and Central Africa sub-regions had grown to more than 6 million tonnes costing over \$1 billion in scarce foreign exchange each year. The cost of importing rice therefore remains a heavy burden on trade balances in the region.

Rice production and productivity, quality and local institutions

While rice is very much a cash crop for small-to medium-scale farmers in the East and Southern Africa (ESA) region, it is more of a subsistence crop in West Africa where most of the continent's rice is produced. In West Africa, 75% of the total production of rice in 1999/2003 is from upland, hydromorphic and lowland ecosystems, with about 25% from irrigated fields (Table 1). Rice is also produced in mangrove production systems and in flooded environments. Research on the mangrove ecology is coordinated by the Rokupr rice research station in Sierra Leone.

Low yield constitutes one of the main challenges of rice production in SSA. In recent years (2001–2005) average rice yields in SSA exhibited a highly variable trend, positive or negative across sub-regions and countries (Africa Rice Trends, WARDA, 2007). The overall rice production increase during the same period was mainly

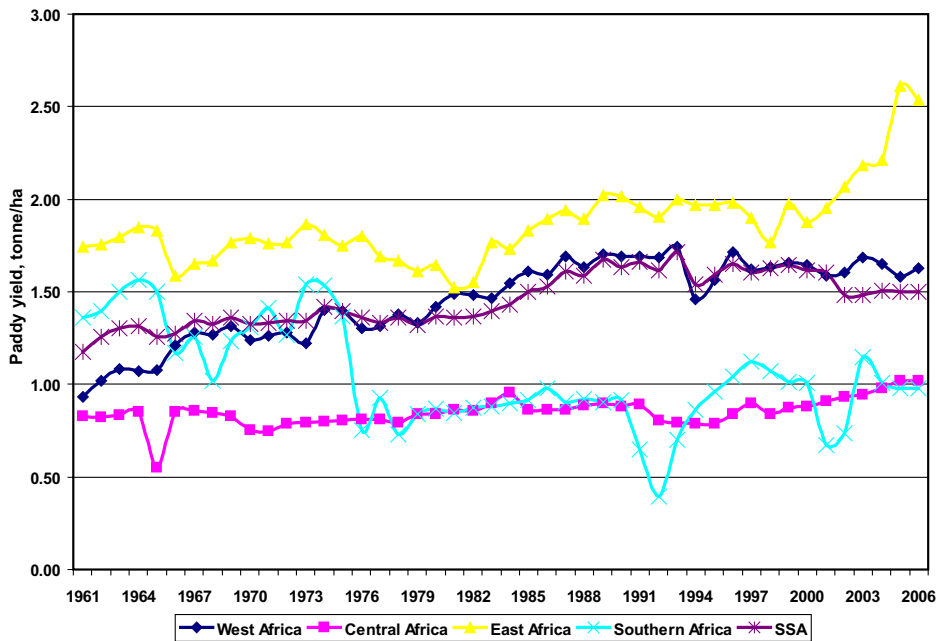
due to the expansion of rice production into marginal areas in West Africa where most production occurs (Table 1).

Table 1. Estimation of rice production trend by each rice production ecology in West Africa during 1984 and 1999/2003

	Area (million ha)		Production (million tonnes/year)		Yield (t/ha)	
	1984	1999/2003	1984	1999/2003	1984	1999/2003
Upland Rainfed	1.5	1.8	1.5	1.8	1	1
lowland	1.5	1.8	0.75	3.4	1.4	2.0
Irrigated lowland	0.23	0.56	0.64	1.9	2.8	3.4
Total	2.6	4.7	3.4	7.7	1.3	1.6

Source: CCER on Integrated Genetic and Natural Resources Management, Gurdev Kush, Toshiyuki Wakatsuki and Glitho Isabelle Adole, 22 January–10 February 2006. Cotonou, Benin: WARDA.

Another challenge is the inferior quality of domestic rice *vis à vis* imported rice. Domestic rice is of uneven quality, has impurities, and is usually sold in bulk in unbranded 5kg bags at a discount of 30% to 50% compared to imported rice. There are exceptions to this, as in Guinea (Conakry) and in Mali, where local rice (for certain varieties) receives a price premium. In order to improve quality of local rice, institutional innovations are needed that make producers more responsive to end-user requirements and attach much more importance to milling and cleaning, and to identity preservation (no mixing of different rice varieties).



Source: WARDA (2007) *Africa Rice Trends*.

Figure 1. Evolution of paddy rice yields in sub-Saharan Africa (1961–2006)

The institutional environment for the development of rice production in SSA represents a third challenge. It is gradually improving as a result of NEPAD's (New Partnership for Africa Development) focus on agriculture with the CAADP (Comprehensive Africa Agricultural Development Programme), the African Rice Initiative (ARI), and efforts by WARDA and its many partners, particularly its Council of Ministers (COM). How to create and support effective institutions is a major challenge.

The truth of the matter is that in SSA growth in rice demand as a preferred staple is so strong that production intensification and higher yields per hectare will not be sufficient to fill the gap and meet rice demand. Unlike in Asia during the green revolution, productivity gains are likely to come in small increments due to the diverse nature of Africa's cropping systems (Balasubramanian *et al.*, 2007). Yet the potential for growth in the African rice sector is

enormous. A rapid increase in the area under rice, irrigated as well as rainfed, is necessary. In particular, the development of new irrigated rice schemes is vital. Only about 17% of the rice area in Africa is irrigated. Asia, in contrast, has about 57% of the rice area under irrigation, but has little or no room for further expansion. Indeed, Ram C. Chaudhary and Dat Van Tran (1999) seriously consider whether Africa can be the future rice bowl for Asia. By 2010, Asia may no longer have net rice exports because of increasing population and consumption, and decreasing land, labor, water and other resources. Instead, by 2020, it is expected that Asia may become a rice-importing continent. Chandhary and Dat Van Tran highlight that millions of hectares of land appropriate for rice growing lie idle in Africa. Water and other resources are available and plentiful. They add that there are other comparative advantages of Africa, which can complement Asian strengths. In addition, they argue that Asia-Africa cooperation in rice production can convert many African countries from net rice importers to net rice exporters, as well as provide hope for Asian countries to continue filling their rice bowls.

Unit 2 – Major rice production systems in sub-Saharan Africa (SSA) and their environments

West African rice ecosystems are conventionally classified as irrigated, rainfed-lowland, rainfed-upland, mangrove swamp and deep-water systems. The total area under rice cultivation is currently about 4.4 million hectares (ha), with the rainfed upland and rainfed lowland ecosystems each accounting for about 1.7m ha and irrigated rice for another 0.5m ha, making these the high-impact ecologies (see Table 2).

Table 2. Total area (hectares) under rice cultivation in various ecologies across countries in West Africa

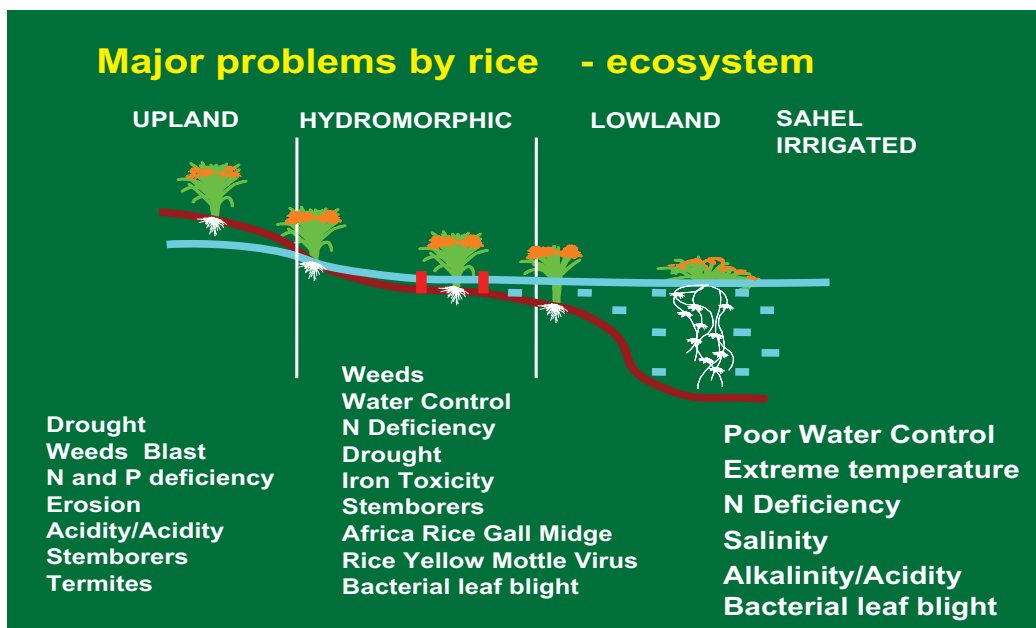
Country	Total area (ha)	Mangrove swamp	Deep water	Irrigated lowland	Rainfed lowland	Rainfed upland
Mauritania	23,000	0	0	23,000	0	0
Senegal	75,000	6,000	0	33,750	35,250	0
Mali	252,000	0	161,280	52,920	30,240	7,560
Burkina Faso	25,000	0	0	6,750	16,250	2,000
Niger	28,000	0	14,000	14,000	0	0
Chad	31,000	0	28,520	620	1,860	0
Cameroon	15,000	0	0	14,700	300	0
Gambia	19,000	2,660	0	1,330	12,160	3,040
Guinea-Bissau	65,000	31,850	0	0	14,300	18,850
Guinea	650,000	84,500	65,000	32,500	162,500	305,500
Sierra Leone	356,000	10,680	0	0	103,240	245,640
Liberia	135,000	0	0	0	8,100	126,900
Côte d'Ivoire	575,000	0	17,250	34,500	69,000	454,250
Ghana	81,000	0	0	12,150	12,150	56,700
Togo	30,000	0	0	600	5,400	24,000
Benin	9,000	0	0	360	360	8,190
Nigeria	1,642,000	16,420	82,100	262,720	788,160	492,600
Total West Africa	4,011,000	160,440	360,990	481,320	1,243,410	1,764,840

Source: Lançon F. and O. Erenstein (2002)

Rainfed upland

Rice yields in upland systems average about 1 t ha⁻¹. Weed competition is the most important yield-reducing factor (Johnson *et al.*, 1997) followed by drought, blast, soil acidity and general soil infertility. Farmers traditionally manage these stresses through long periods of bush fallow. More recently, population growth has led to a dramatic reduction in fallow periods and to extended periods of cropping in many areas, with resulting increases in weed pressure

and in soil infertility. Additional weed competition further reduces labor productivity in upland rice-based production systems, which are already generally limited by labor availability during the main cropping season. Farmers also face increased risks of crop failure and generally lower productivity levels. Very early maturing varieties with tolerance to drought and blast are required in the dry zones where the growing season is short, while medium to late maturing and acid-tolerant varieties are needed for higher rainfall areas. Desirable agronomic traits include good vigor at seedling and vegetative stages for weed suppression, intermediate to tall stature, lodging resistance and moderate tillering ability. Of great importance is tolerance to soil acidity and P deficiency. Modest inputs of organic or inorganic fertilizer or soil amendments, such as rock phosphate, or the use of fallow legumes may counter soil fertility decline in the upland environments and improve yields. Fallow legumes may also reduce weed infestation levels in the following rice crop.



Source: Africa Rice Center (WARDA)

Figure 2. Rice production constraints across ecosystems in West Africa

Rainfed lowland

Rice yields in rainfed lowlands (flood plains and valley bottoms) depend on the degree of water control and vary from 1 to 3 t ha⁻¹. These systems have a high potential for intensification, which is pushed by local land pressures and pulled by urban market demand. With improved water control, use of external inputs may become attractive and rice yields may be increased rapidly in these systems that are inherently much more stable than the upland areas. Biophysical factors affecting rice yield in rainfed lowland systems include weeds, drought, flooding, soil nutrient supply, iron toxicity, blast, rice yellow mottle virus (RYMV) and African rice gall midge (AfRGM). High yield potential is the priority objective in breeding for rainfed lowlands, combined with weed competitiveness, short duration, resistances to blast, RYMV and AfRGM, and tolerance to iron toxicity. The major socio-economic constraints include resource availability, production risk, knowledge on best-bet crop management practices, and human health problems.

Irrigated rice

Irrigated rice-growing areas are divided into three subcategories based on temperature. Two are found in West and Central Africa: favorable-temperature and low-temperature, tropical irrigated zones. The latter is restricted to the mid-altitude areas of Cameroon. The former is represented by the dry-season irrigated rice that is found in all agro-ecological zones from the rainforest to the Sahel. While nearly all the rice grown in Mauritania (Sahel) is irrigated, only 12–14% (0.5 million ha) of the total rice area in West and Central Africa is irrigated. This includes substantial areas in Cameroon (80%), Niger (55%), Mali (30%) and Burkina Faso (20%). Irrigated rice in these countries (except Cameroon) is mainly in the Sudan Savanna and Sahel, which account for nearly 60% of the irrigated rice area in West and Central Africa. In Côte d'Ivoire, about 24,500 ha (7% of total area) is irrigated. Yield potential (10 t/ha) is higher in these drier zones than in others, because of high solar radiation and low disease stress.

Unit 3 – Addressing the challenge of low productivity in African rice ecologies: NERICA® varieties

Nearly half of sub-Saharan Africa's 700 million people live below the poverty line (World Development Indicators, 2004). With population growth rate exceeding the growth rate in regional food production, and with only limited foreign resources to sustain increased levels of imports, the future for Africa's poor appears grim.

WARDA's breakthrough in producing the 'New Rice for Africa' (NERICA), based on crossings between African rice (*Oryza glaberrima* Steud.) and Asian rice (*O. sativa* L.), offers welcome relief to Africa's rice farmers. It is a new and unique opportunity for sustainable agricultural development in the rainfed environments where most of Africa's rice farmers earn a living.

NERICA varieties have high yield potential and short growth cycle. Several of them possess early vigor during the vegetative growth phase and this is a potentially useful trait for weed competitiveness. Likewise, a number of them are resistant to African pests and diseases, such as the devastating blast, to rice stemborers and termites. They also have higher protein content and amino acid balance than most of the imported rice varieties. Participatory varietal selection (PVS) trials in rainfed environments across WCA have met with an enthusiastic response from farmers.

NERICA: ORIGINS, NOMENCLATURE AND IDENTIFICATION CHARACTERISTICS

Unit 1 – What is NERICA?



Figure 3. NERICA plants thriving in a farmer's field

The term NERICA stands for 'New Rice for Africa', an extended family of some 3,000 siblings.

Large variation exists therefore amongst NERICA varieties, suggesting that the agro-physiological traits of NERICA can not be generalized. NERICA is used to refer to genetic material derived from the successful crossing of the two species of cultivated rice,

the African rice (*O. glaberrima* Steud.) and the Asian rice (*O. sativa* L.), to produce progeny (known as interspecifics) that combine the best traits of both parents. These include high yields from the Asian parent and the ability from the African parent to thrive in harsh environments. In 2000, the interspecific progeny were dubbed New Rice for Africa (NERICA) and the name trademarked two years later.

NERICA rice is produced through conventional crossbreeding and is therefore not genetically modified rice!

NERICA is a new group of upland rice varieties that perfectly adapt to the rainfed upland ecology in sub-Saharan Africa (SSA), where smallholder farmers lack the means to irrigate or apply chemical fertilizers or pesticides. However, NERICA varieties also respond even better than traditional varieties to higher inputs.

The upland or dryland ecology, where rainfed rice is grown without standing water, represents about 40% of the total area under rice cultivation in West and Central Africa (WCA) – the rice belt of Africa – and employs 70% of the region's rice farmers.

The new varieties with higher yield potential are spreading faster than any new farm technology ever before introduced in Africa, covering by 2006 an estimated area of 200,000 hectares in West, Central, East and Southern Africa.

The NERICA seeds offer hope to millions of poor rice farmers, and for countless others who struggle in urban squalor, spending most of their meager income on rice.

O. sativa
as female parent

O. glaberrima
as male parent



Figure 4. Development of interspecific lines

Unit 2 – Where, When and How was NERICA® rice developed?

The NERICA rice varieties were developed at the Africa Rice Center (WARDA). In the early 1990s, a team of rice breeders led by Dr Monty Patrick Jones at the main M'bé research center of WARDA in Bouaké, Côte d'Ivoire, developed stable and fertile progeny from crosses between Asian rice, *O. sativa* L. and African rice, *O. glaberrima* Steud. (Jones *et al.*, 1997b; Jones *et al.*, 1998a).

The first generation of NERICA varieties 1 to 11, including the WAB450 progeny, was developed from crosses of the existing released variety CG 14 (*O. glaberrima* Steud.) and WAB56-104, which belongs to the subspecies japonica of *O. sativa* L., an upland

improved variety. On the other hand, NERICAs 12 to 18 are progeny of two series of crosses, using the same *O. glaberrima* (CG 14) parent but two different *O. sativa* parents (WAB56-50 and WAB181-18). They include the series of WAB880 and WAB881 progeny (Table 5; Annex).

The parentage of the two parents of WAB56-50 and WAB 56-104 includes the following:

WAB56-50-IDSA6/IAC164
WAB 56-104-IDSA6/IAC164

IDSA6-COLOMBIA 1/M 312 A-74-2-8-8
IAC164-DOURADO PRECOCE/IAC 1246

The exact parentage of WAB 181-18 is not reported but is believed to be WAB mixed F₁s # 1).

Morphologically diverse, genetically stable and fully fertile, these interspecific progeny have been developed either through the refined method of conventional breeding, or with the use of specifically-developed anther culture and double-haploidization techniques to overcome sterility and to hasten the breeding process. Crosses were made and embryo rescue was used to remove fertilized embryos and grow them in artificial media. Anther culture allowed rapid fixation and helped to retain interspecific lines combining desirable features of the two rice species.

WARDA's lead role in interspecific hybridization for rice

This achievement was indeed a scientific breakthrough. Previous conventional breeding efforts elsewhere in the world to develop interspecific hybrids of rice had failed, yielding only infertile offspring of the two species being used for crossing.

¹WAB signifies a variety or line developed at WARDA Bouaké (WARDA Headquarters in Côte d'Ivoire).

This breakthrough established WARDA's lead role in interspecific hybridization and anther culture for rice (Jones, 1998b). Exploitation of the *O. glaberrima* gene pool increased the scope for the development of low management input plant types (Jones *et al.*, 1997a; Dingkuhn *et al.*, 1998). *O. glaberrima* originates in Africa and is resistant to a number of major African insect pests and diseases such as stem borers and rice blast. *O. glaberrima* is also very competitive with weeds (Audebert *et al.*, 1998; Johnson *et al.*, 1998), the main constraint to rice production across ecologies in SSA.

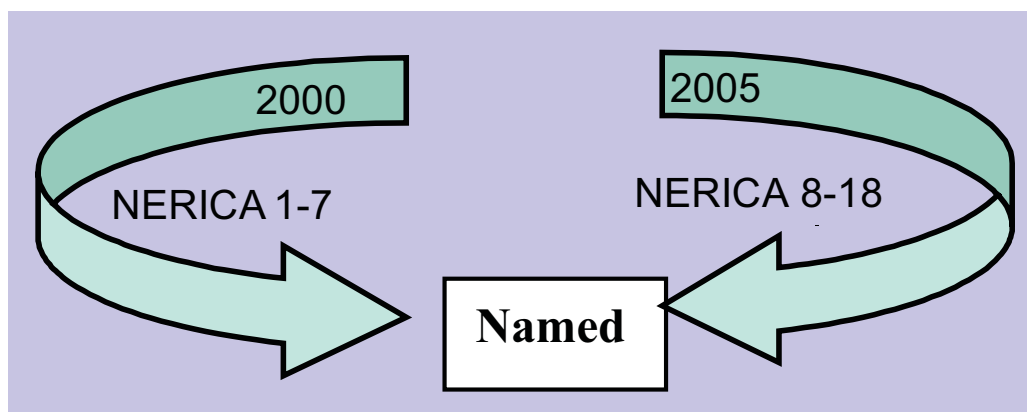
How many NERICA rice varieties have been developed so far?

Several hundred upland interspecific progeny have been generated, thereby opening new gene pools and increasing the biodiversity of rice for the world of science and end-user farmers. There are upland NERICAs and lowland irrigated NERICAs.

Of course, some of these siblings have pushed their way to the fore more than others. That is why even the best-informed NERICA watchers still think of NERICA1 through 18 – the first released upland varieties in West and Central Africa. However, some 60 later siblings directed at lowland-irrigated cropping are being grown in widespread evaluation trials throughout sub-Saharan Africa.

Eighteen upland NERICA varieties characterized and named by WARDA

As of December 2005, WARDA had named a total of 18 upland NERICAs following their selection by farmers during participatory varietal selection trials across SSA. Some of these NERICA varieties have already been released, or are in the pipeline for release, and being grown under rainfed upland conditions by farmers in various countries in SSA (Table 3).



Progress in naming the NERICA varieties

Experience has shown that potential yield of the rainfed upland NERICA depends on various factors, including but not limited to the variety, the fertility status of the soil, the rainfall and the management practices of the farmer.

Average grain yield recorded in on-farm trials of NERICA adaptability conducted without fertilizer application in selected countries in West Africa is summarized below (Table 3).

Table 3. Grain yield of NERICA varieties grown by farmers without fertilizer application in selected countries

Country	Sites	Variety name	kg ha ⁻¹
Côte d'Ivoire	Boundiali	NERICA2	1369
		NERICA3	1112
		NERICA4	1262
	Danane	NERICA2	1947
		NERICA3	1871
		NERICA4	1517
	Gagnoa	NERICA2	2279
		NERICA3	1706
		NERICA4	1826
Mali	Samanko	NERICA2	1498
		NERICA6	998
	Sikasso	NERICA2	1720
		NERICA6	1055
Togo	Amlame	NERICA1	2083
		NERICA4	1352

Source: WARDA Database, PVS Research

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On the other hand, Table 4 below summarizes grain yield of NERICA varieties recorded in selected countries where a little chemical fertilizer [varying in quantity across sites but mostly a basal 50 kg ha⁻¹ NPK (15:15:15) with 30 kg ha⁻¹ N as urea] was applied to the crop.

Table 4. Grain yield of NERICA grown on-farm with fertilizer application in selected countries.

Country	Sites	Variety name	kg ha ⁻¹
Ghana	Nyankpala	NERICA1	2576
		NERICA4	2531
		NERICA6	3171
	Golinga 1	NERICA1	4982
		NERICA4	3653
		NERICA6	4955
	Golinga 2	NERICA1	3288
		NERICA4	2384
		NERICA6	3593
Guinea	Faranah, Dantilia	NERICA1	3950
	Faranah, Dantilia	NERICA3	4270
Mali	Longorola	NERICA8	1683
		NERICA9	1408
	Finkolo	NERICA8	3400
		NERICA9	4058
Kenya	Kari Kibos	NERICA1	5194
		NERICA4	5772
		NERICA10	4663
		NERICA11	5451
Tanzania		NERICA2	4540
		NERICA3	4440
		NERICA4	5100
		NERICA7	4600
		NERICA4	4500–5000
Ethiopia	Somali region	NERICA1 (intermittent irrigation)	5000–6000
		Oromia region	NERICA1 (rainfed only)

Source: JICA Seminar on Promotion of Rice Production and Dissemination in Africa, Accra, Ghana, 6–8 December 2006; SG2000 presentation at the WARDA Research Evaluation and Planning Meeting, Cotonou, Benin, 2006; WARDA Annual Report, 2003–2004

Ratooning performance of NERICA varieties

Studies conducted in the savanna zone of Dévé, Benin in 2006 on the named 18 rainfed upland NERICA indicated a large variation in the ratoon performance among these varieties, with a ratoon yield ranging from 39% (NERICA17) to 13% (NERICA2) of the main crop yield, bringing the total grain yield per plot and per cropping season up to about 6500 kg ha⁻¹. NERICA14, NERICA15, NERICA17 and NERICA18 exhibited the highest ratoon yield performance. The mechanism contributing to the ratooning ability of these short-duration NERICA varieties was not investigated in the reported study (Sanni *et al.*, 2007, personal communication). Similar findings on the ratoon yield potential of interspecific progeny, including the NERICAs were also reported in Kenya (Kouko *et al.*, 2006)

Table 5. Upland NERICA varieties with their pedigree*.

Variety	Pedigree	Backcross
NERICA1	WAB 450-I-B-P-38-HB	WAB 56-104/CG 14//WAB56-104
NERICA2	WAB 450-11-1-P31-1-HB	WAB 56-104/CG 14//WAB56-104
NERICA3	WAB 450-I-B-P-28-HB	WAB 56-104/CG 14//WAB56-104
NERICA4	WAB 450-I-B-P-91-HB	WAB 56-104/CG 14//WAB56-104
NERICA5	WAB 450-11-1-1-P31-HB	WAB 56-104/CG 14//WAB56-104
NERICA6	WAB 450-I-B-P-160-HB	WAB 56-104/CG 14//WAB56-104
NERICA7	WAB 450-I-B-P-20-HB	WAB 56-104/CG 14//WAB56-104
NERICA8	WAB 450-1-BL1-136-HB	WAB 56-104/CG 14//WAB56-104
NERICA9	WAB 450-B-136-HB	WAB 56-104/CG 14//WAB56-104
NERICA10	WAB 450-11-1-1-P41-HB	WAB 56-104/CG 14//WAB56-104
NERICA11	WAB 450-16-2-BL2-DV1	WAB 56-104/CG 14//WAB56-104
NERICA12	WAB 880-1-38-20-17-P1-HB	WAB 56-50/CG 14//WAB56-50
NERICA13	WAB 880-1-38-20-28-P1-HB	WAB 56-50/CG 14//WAB56-50
NERICA14	WAB 880-1-32-1-2-P1-HB	WAB 56-50/CG 14//WAB56-50
NERICA15	WAB 881-10-37-18-3-P1-HB	CG 14/WAB 181-18//WAB181-18
NERICA16	WAB 881-10-37-18-9-P1-HB	CG 14/WAB 181-18//WAB181-18
NERICA17	WAB 881-10-37-18-13-P1-HB	CG 14/WAB 181-18//WAB181-18
NERICA18	WAB 881-10-37-18-12-P3-HB	CG 14/WAB 181-18//WAB181-18

* Note: the first generation of NERICAs, including the series of WAB450, WAB880 and WAB881, was developed from the crosses between CG 14 / WAB56-104, WAB56-50 / CG 14 and CG 14 / WAB181-18, respectively. CG 14 is an *O. glaberrima* variety, while WAB56-50 and WAB181-18 are improved *O. sativa japonica*-type varieties developed by WARDA.

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Table 6. NERICA varieties released and adopted in sub-Saharan Africa as of December 2006

NERICA Country	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total per country
Benin	A	A	A																3
Burkina Faso												R	R		A		R	A	5
Congo Brazza										A									1
Congo DRC				A		A	A												3
Côte d'Ivoire	R	R	A	A	A														5
Ethiopia	A	A	R	R															4
Gambia	A	A	A	A	A	A	A												7
Ghana	R	A																	2
Guinea	R	R	R	R	R	R	R												7
Kenya	A		A							A	A								4
Madagascar		A	A																2
Mali				R					A	A				A				A	5
Nigeria	R	R																	3
Sierra Leone	A	A	A	A	A														5
Sudan				A			A												2
Togo	A		A	A															3
Uganda	A		A	R															3
Total	11	9	10	10	4	3	4	0	1	3	1	1	1	1	1	0	1	2	

Source: WARDA, 2006

R – Frequency of release of NERICA varieties (19); frequency of NERICA adoption (44) and grown by farmers though might not be officially released in the country

World-class awards for Upland NERICA development

Dr Monty Jones, Father of the NERICAs, became in 2004 the first African laureate to receive the World Food Prize for developing the NERICA rice varieties. Four years earlier, the Consultative Group on International Agricultural Research (CGIAR) presented the King Baudouin Award to the Africa Rice Center (WARDA) for the NERICA breakthrough.

Subsequently, the NERICA varieties technology has spilled over into research for developing suitable rice plants for other high-impact ecologies, including the high-potential irrigated and rainfed lowlands of sub-Saharan Africa.

NERICA for the high-potential irrigated and rainfed lowlands

Contributor: Moussa Sié

Characteristics and potential of African rainfed lowlands

African lowlands constitute one of the most complex rice ecologies in the world. The rainfed lowlands – where rice is grown in banded fields that are flooded for at least part of the growing season – are more fertile than the uplands and have the added advantage of opportunities for irrigation. Most of the traditional lowland rice varieties grown in West Africa have a narrow genetic base, which leads to their vulnerability to diseases and pests. Yet lowlands account for about 30% of the area under rice cultivation in West and Central Africa.

The potential of irrigated and rainfed lowlands is much higher than that of upland ecologies, as they are suited to cropping intensification, with the possibility of growing two or more crops per year. In West Africa alone, out of a total rice area estimated at more than 20 million hectares, only 2 million hectares of lowlands are cultivated for rice, producing an average yield of 3 tonnes per hectare. The lowlands, therefore, offer

great potential for the sustainable expansion and intensification of rice and can help to feed the region's expanding population. Given such high potential, the new lowland NERICAs are expected to make an even bigger impact than the upland NERICAs, which previously unleashed the potential of the upland rice ecologies across Africa.

Development process and potential of irrigated and lowland NERICAs

The development of irrigated and rainfed lowland NERICAs from *glaberrima* and *sativa* (*indica* subspecies) crosses was initiated in 2000 by a research team led by Dr Kouamé Miézan, then principal irrigated rice breeder and Head of WARDA's Sahel station in Saint-Louis, Senegal (WARDA, 2000). In 1996 Dr Moussa Sié, WARDA's lowland rice breeder, but then a research fellow in the irrigated rice breeding program in Saint-Louis and a member of the team, undertook pioneering work in collaboration with other national partners to develop and adapt newly-derived interspecific progeny to the rainfed-lowland production environments of West Africa.

This groundbreaking work led to the development at WARDA's Sahel station of hundreds of interspecific progeny from the indigenous African rice (*O. glaberrima* Steud.) and the Asian species (*O. sativa* L. subsp. *indica*). These were tailored to suit the irrigated and rainfed lowland ecologies in SSA. Five *glaberrima* lines, comprising TOG5681, TOG5674, TOG5675, TOG7291 and TOG5672, known to be highly resistant to the rice yellow mottle virus (RYMV), were crossed with *sativa* cultivars – mostly *indica* – including Jaya, Bg90-2, Bg380-2, I Kong Pao, ITA123 (*japonica*), IR28, IR64, IR1529-680-3, IR13240-108-2-2-3, IR29725-40-3-2-3, IR31785-58-1-2-3-3, IR31851-96-2-3-2-1, IR32307-107-2-2-3. Not all combinations were successful. However, TOG5681 x IR64, TOG5681 x 1529-680-3, TOG5674 x IR31785-58-1-2-3-3 and TOG5675 x IR28 were among the most promising crosses.



This variety is one of the NERICA-L released in Burkina Faso and Mali and can reach a yield potential of 6-7 tonnes per hectare

Major differences in the process of upland and lowland NERICA varieties development

The main difference between the development of lowland NERICA and that of the upland interspecifics was in the selection of the Asian rice varieties for the crosses. The Asian rice *O. sativa* has two main strains, including the japonica (traditional rainfed or 'upland' rice) and indica (traditional irrigated or 'lowland' rice). In the creation of upland NERICA varieties, japonica varieties were used in the crosses, while the indica subspecies was used for developing the new lowland rice.

As in the process of upland NERICA development, the initial problem was again hybrid sterility (infertile offspring of the crosses). The sterility blockage was overcome by backcrossing (crossing the hybrid to *O. sativa* to restore fertility).

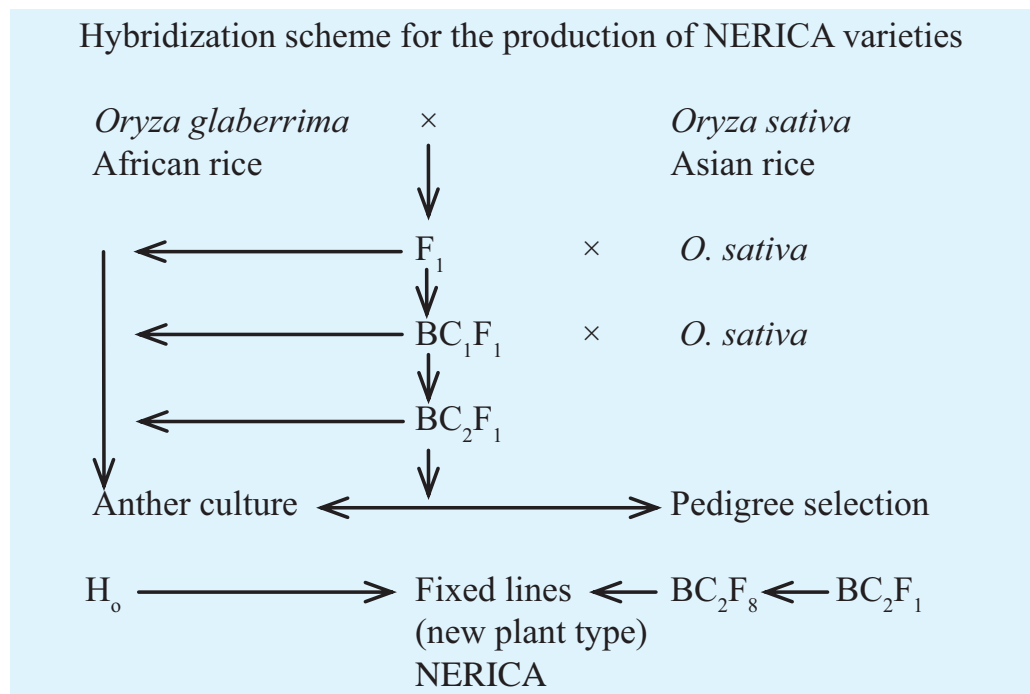


Figure 5. How the development team arrived at the new Lowland NERICA varieties

After four backcrosses (*sativa* as recurrent), over 500 highly-fertile fixed lines (85 – 100% fertility) were selected and evaluated in tandem with NARS (shuttle breeding) in observational nurseries under irrigated conditions in Senegal and Côte d’Ivoire, and under irrigated – and rainfed – lowland conditions in Burkina Faso, Mali and Togo for adaptation, and with the WARDA’s plant pathologist at M’bé for resistance to RYMV. These lines were evaluated for phenotypic acceptability, yield potential, RYMV resistance, nitrogen – use efficiency and adaptation to different water regimes (hydromorphic to valley bottoms in Burkina Faso).

Through a strong networking approach supporting the shuttle breeding, undertaken with the active involvement of the West and Central Africa Regional Rice Network (ROCARIZ) and the International Network for Genetic Evaluation of Rice (INGER-Africa), WARDA has been able to accelerate the selection process and achieve wide adaptability of the Lowland NERICAs in Togo, Burkina Faso, Mali and other countries in West Africa.

Out of the hundreds of interspecific progenies developed, 60 were particularly acclaimed by farmers in several countries through the participatory variety selection (PVS) process – an approach that was used successfully in accelerating the dissemination of the upland NERICA varieties. In 2006 these progenies were named the New Rice for African Lowlands (NERICA-L), of which several have been released and grown in farmers' fields in Burkina Faso, Mali, Togo, Sierra Leone, Niger and Cameroon (Table 7).

Table 7. List of released irrigated-lowland NERICA varieties (NERICA-L) in West and Central African countries as of May 2007

Country	Varieties			
Burkina Faso	NERICA-L-19 (FKR 62N)	NERICA-L-20 (FKR 60N)	NERICA-L-41 (FKR 56N)	NERICA-L-60 (FKR 58N)
Mali	NERICA-L-20 (N2)	NERICA-L-42 (N1)		
Togo	NERICA-L-19	NERICA-L-34		
Sierra Leone	NERICA-L-19	NERICA-L-20		
Cameroon	NERICA-L-19			
Niger	NERICA-L-39	NERICA-L-49		

Biodiversity sustained as a result of NERICA development

The development of interspecific rice varieties for various ecologies is a significant international public good. The Africa Rice Center (WARDA) has generated several hundred NERICA lines, opening new gene pools and increasing the biodiversity of rice available to the world of science. This development of the NERICA varieties is further advancing the farm-level agro-biodiversity of rice in the high-impact ecologies.

By unlocking the treasure store of genes in African rice (*Oryza glaberrima*), WARDA has presented the global rice research community with an opportunity to exploit the proffered biodiversity.

Award for the development of NERICA lowland varieties

In 2006 Dr Moussa Sié was awarded the prestigious International Koshihikari Rice Prize of Japan in recognition of his leadership in the development of the new rice for African lowlands (NERICA-Lowland).

Rapid headway made by NERICA lowland varieties in farmers' fields

By December 2006, lowland NERICA varieties were released in Mali and Burkina Faso (Figure 6) and were being tested in other countries. The most popular among rice farmers in Burkina Faso were WAS 161-B-9-3 (TOG 5681 / 4*IR 64); WAS 191-9-3 (IR 64 / TOG 5681 // 4*IR 64); WAS 122-IDSA-1-WAS-1-1-B (TOG 5681 /3*IR 64) and WAS 122-IDSA-1-WAS-6-1(TOG 5681 / 3*IR 64). Their potential yields range from 6–7 tonnes per hectare (as against an average grain yield of 3 tonnes per hectare for West Africa), and they have a growth duration of 120 days. These varieties exhibit good resistance to major lowland stresses and have also responded well to nitrogen fertilizer application (WARDA, 2005/2006).

Table 8. The 60 lowland NERICA varieties with their pedigree.

Variety name	Pedigree	Parents
NERICA-L-1	WAS 122-IDS A 10-WAS 1-1-FKR 1	TOG5681/3*IR64
NERICA-L-2	WAS 122-IDS A 10-WAS 6-1-FK R 1	TOG5681/3*IR64
NERICA-L-3	WAS 122-IDS A 11-WAS 11-4-FKR 1	TOG5681/3*IR64
NERICA-L-4	WAS 122-IDS A 11-WAS 8-2	TOG5681/3*IR64
NERICA-L-5	WAS 122-IDS A 12-WAS B-FKR 1	TOG5681/3*IR64
NERICA-L-6	WAS 122-IDS A 13-WAS 10-FKR 1	TOG5681/3*IR64
NERICA-L-7	WAS 122-IDS A 13-WAS 13-3-3 FKR 1	TOG5681/3*IR64
NERICA-L-8	WAS 122-IDS A 14-WAS B-FKR 1	TOG5681/3*IR64
NERICA-L-9	WAS 122-IDS A-10-WAS-3-1-TGR 3	TOG5681/3*IR64
NERICA-L-10	WAS 122-IDS A-10-WAS-7-2-FKR 1-TGR 89	TOG5681/3*IR64
NERICA-L-11	WAS 122-IDS A-11-WAS-10-2-TGR 60	TOG5681/3*IR64
NERICA-L-12	WAS 122-IDS A-11-WAS-B-IER-11-19	TOG5681/3*IR64
NERICA-L-13	WAS 122-IDS A-13-WAS 10-WAB- B-TGR 5	TOG5681/3*IR64
NERICA-L-14	WAS 122-IDS A-1-WAS 2-WAB 1-TGR 6	TOG5681/3*IR64
NERICA-L-15	WAS 122-IDS A-1-WAS-2	TOG5681/3*IR64
NERICA-L-16	WAS 122-IDS A-1-WAS-2-B-1-TGR 132	TOG5681/3*IR64
NERICA-L-17	WAS 122-IDS A-1-WAS-2-WAB 2-TGR 7	TOG5681/3*IR64
NERICA-L-18	WAS 122-IDS A-1-WAS-4-B-1-TGR 121	TOG5681/3*IR64
NERICA-L-19	WAS 122-IDS A-1-WAS-6-1	TOG5681/3*IR64
NERICA-L-20	WAS 122-IDS A-1-WAS-B	TOG5681/3*IR64
NERICA-L-21	WAS 124-B-3-4-FKR 1	TOG5681/3*IR1529- 680-3-2
NERICA-L-22	WAS 126-B-8-1-FKR1-TGR 96	TOG 5681 / 2*IR 64 //IR 31785-58-1-2-3-3
NERICA-L-23	WAS 127-IDS A 2-WAS 3-5-FKR 1	TOG 5681/2*IR 64// IR31851-96-2-3-2-1
NERICA-L-24	WAS 127-IDS A 2-WAS 3-6-FKR 1	TOG 5681/2*IR 64// IR31851-96-2-3-2-1
NERICA-L-25	WAS 127-IDS A-2-WAS-1	TOG 5681/2*IR 64// IR31851-96-2-3-2-1
NERICA-L-26	WAS 161-B-1-1-FKR 1	TOG5681/4*IR64
NERICA-L-27	WAS 161-B-2-B-1	TOG5681/4*IR64
NERICA-L-28	WAS 161-B-2-B-2	TOG5681/4*IR64
NERICA-L-29	WAS 161-B2-B3	TOG5681/4*IR64
NERICA-L-30	WAS 161-B-2-B-4	TOG5681/4*IR64
NERICA-L-31	WAS 161-B-4-1-FKR 1	TOG5681/4*IR64
NERICA-L-32	WAS 161-B-4-B-1-TGR 51	TOG5681/4*IR64
NERICA-L-33	WAS 161-B-4-B-2	TOG5681/4*IR64
NERICA-L-34	WAS 161-B-6-3-FKR 1	TOG5681/4*IR64
NERICA-L-35	WAS 161-B-6-4-FKR 1	TOG5681/4*IR64
NERICA-L-36	WAS 161-B-6-B-1	TOG5681/4*IR64
NERICA-L-37	WAS 161-B-6-B-4	TOG5681/4*IR64

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NERICA-L-38	WAS 161-B-6-B-B-1-B	TOG5681/4*IR64
NERICA-L-39	WAS 161-B-6-WAB-B-TGR 16	TOG5681/4*IR64
NERICA-L-40	WAS 161-B-9-1-FKR 1	TOG5681/4*IR64
NERICA-L-41	WAS 161-B-9-3	TOG5681/4*IR64
NERICA-L-42	WAS 161-IDS A-3-WAS-B-IER-2-4	TOG5681/4*IR64
NERICA-L-43	WAS 163-B-5-3	TOG 5674/4*IR 31785
NERICA-L-44	WAS 186-5-3-FKR 1	TOG5681/5*IR64
NERICA-L-45	WAS 186-B-8-B-1	TOG5681/5*IR64
NERICA-L-46	WAS 186-B-8-B-2	TOG5681/5*IR64
NERICA-L-47	WAS 189-4	TOG 5675/4*IR 28
NERICA-L-48	WAS 191-10-3-FKR 1	IR 64/TOG 5681//4 *IR 64
NERICA-L-49	WAS 122-IDS A-1-B-IER-18-6	TOG5681/3*IR64
NERICA-L-50	WAS 191-10-4-FKR 1-TGR 123	IR 64/TOG 5681//4 *IR 64
NERICA-L-51	WAS 191-10-WAB-B-TGR 23	IR 64/TOG 5681//4 *IR 64
NERICA-L-52	WAS 191-1-5-FKR 1	IR 64/TOG 5681//4 *IR 64
NERICA-L-53	WAS 191-1-7-TGR 90	TOG5681/4*IR31785
NERICA-L-54	WAS 191-4-10	IR 64/TOG 5681//4 *IR 64
NERICA-L-55	WAS 191-8-1-FKR 1	IR 64/TOG 5681//4 *IR 64
NERICA-L-56	WAS 191-8-3	IR 64/TOG 5681//4 *IR 64
NERICA-L-57	WAS 191-9-B-2	64/TOG 5681//4 *IR 64
NERICA-L-58	WAS 191-9-WAB-B-TGR 24	IR 64/TOG 5681//4 *IR 64
NERICA-L-59	WAS 192-3-WAB-B-TGR 25	IR 31785//TOG 5674/4*IR31785-58
NERICA-L-60	WAS 191-9-3-FKR-1	IR 64/TOG 5681//4 *IR 64

TOG5681 is an O. glaberrima variety; IR numbers are O. sativa varieties

Important Note

Although several irrigated lowland NERICA varieties have been released in six countries in West Africa, further information is still being gathered in farmers' fields in about 20 countries across SSA on the performance and tolerance levels of these varieties to abiotic and biotic stresses across ecologies; farmers being the ultimate judges of any new technologies, including the NERICA varieties.

Irrigated and lowland NERICA varieties are not considered further in this Compendium. We focus instead on the first generation of the NERICA technology – the upland NERICA varieties. Henceforth, unless otherwise indicated, the use of the term NERICA varieties in the rest of this document refers to the 18 named upland NERICA varieties.

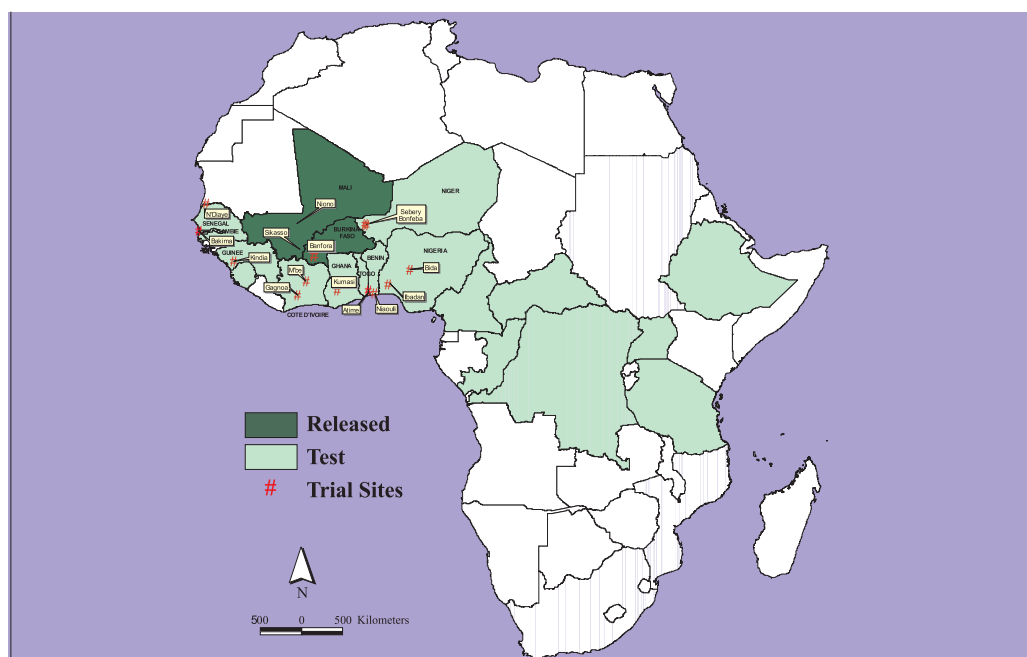


Figure 6. Countries in sub-Saharan Africa where irrigated-lowland NERICA varieties were released or were being tested (as of December 2006)

Unit 3 – NERICA® variety key characteristics – a quick glance at the NERICA® advantages

Background information

The NERICAs have been evaluated and characterized for a range of agronomic traits and reaction to key African endemic diseases and pests. NERICA varieties generally have shorter growth duration than most traditional rice varieties. A number of NERICA varieties possess early vigor, which is an important trait for weed

Module 2

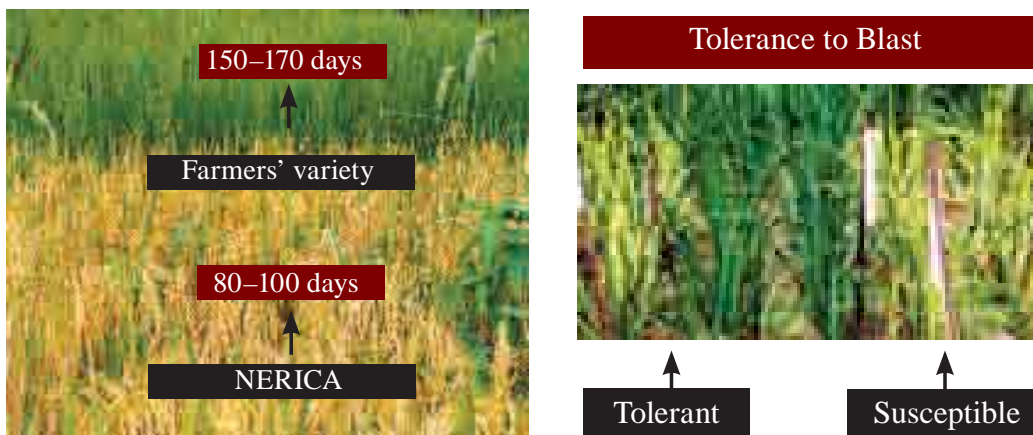
NERICA: origin, nomenclature and identification characteristics

competitiveness in rice, thus improving the productivity of scarce labor. Moreover, some of them also have tolerance to drought and soil acidity. NERICA characteristics include cooking and eating qualities particularly acceptable to local consumers; NERICA protein content is generally higher than that of much of the imported rice widely available in African local markets.

NERICA advantages

Early maturity (by 50–70 days) earlier than farmers varieties
Resistance to local stresses (blast, stem borers, termites)
High yield advantage (up to 6 tonnes per hectare under favourable conditions)
Higher protein content (by 25%)
Good taste

Early maturing (within 80–100 days; i.e. 50–70 days earlier than farmers' varieties) under low altitude conditions (<1,000 meters above sea level masl).



Farmers may be able to grow two crops in one rainy season – with perhaps a legume as the second crop.

Tolerance to Drought

Early vegetative growth contributes to the shorter duration of the upland NERICA varieties which is one of their major attractions for farmers. This can be a useful trait to escape drought or compete with weeds, and it enables farmers to diversify their cropping systems through rotations or intercrops. Some of the second generation NERICA recently characterized by WARDA appear to mature in less than 85 days. Resistance/tolerance to blast, stem borers and termites in NERICA varieties has also been indicated.

Soil tolerance – NERICA2 and NERICA4 have showed tolerance to soil acidity in the Fouta Djallon (middle Guinea; JICA, 2004).

Drought tolerance – preliminary data from WARDA suggest the existence of valuable genetic material among the interspecific progeny for use in drought-prone environments (Module 5; Manneh *et al.*, 2007).

Module 2

NERICA: origin, nomenclature
and identification characteristics

Responsive to fertilization – higher yield (up to 6 tonnes/ha when appropriate levels of fertilizer are used).

Higher protein content – on average by 25%. The Africa-wide benefits of this extra protein (Module 13) can be viewed from many angles: improved health, substitution of costlier protein sources, mental development in youths, etc.

NERICA DISSEMINATION IN SUB-SAHARAN AFRICA (SSA)

Modus operandi: Partnership

The Africa Rice Center (WARDA) *modus operandi* is partnership at all levels. WARDA is recognized as a partnership center with privileged relations with its constituency of NARS.

For accelerated dissemination of improved technologies, including NERICA varieties, WARDA has explored a range of partnership models and adapted several participatory approaches, such as Participatory Variety Selection (PVS), Community-based Seed Production Systems (CBSS) and Participatory Learning and Action Research (PLAR).

A Center-commissioned Evaluation Review (CCER) on partnerships conducted in 2005 was not only the first-ever by WARDA but the first-ever within the CGIAR. The CCER Panel commended WARDA for its boldness in conducting such a review, which not only confirmed WARDA's partnership model as being unique and exemplary, but also highlighted the Center's contribution to reinforcing Africa's capacity for agricultural research. This recognition culminated in December 2006 in WARDA receiving the prestigious United Nations Award for South-South Triangular Partnership for its pioneering efforts in brokering North-South partnerships in order to create hybridized varieties of rice applicable to conditions in the South.

For upstream research and development, the Interspecific Hybridization Project (IHP) model – a triangular South-South partnership – was developed to bring together the pool of expertise from advanced research institutes with that of national programs. IHP was the key to the advancement of upland NERICA varieties in SSA.

It was supported by Japan, the United Nations Development Programme (UNDP), and the Rockefeller and Gatsby Foundations. The research on NERICA varieties has also been sponsored right from the beginning by the CGIAR. Research and development partners in the IHP include the International Rice Research Institute (IRRI); *Centro Internacional de Agricultura Tropical* (CIAT); Japan International Cooperation Agency (JICA); Japan International Research Center for Agricultural Sciences (JIRCAS); *Institut de recherche pour le développement* (IRD); Cornell, Tokyo and Yunnan Universities; and the national programs of African countries.

- ***Mechanisms of partnership:*** The achievements of WARDA's partnerships in germplasm dissemination, including NERICA varieties, are captured through a variety of mechanisms, including networks such ROCARIZ, ARI and INGER-Africa, and collaborative projects such PVS, CBSS, IHP and PLAR. The Center hosts these networks developed and created in close consultation with stakeholders. Activities of these networks and projects have resulted in tangible outputs which have been summarized throughout this document. The following paragraphs provide additional information.
- ***Participatory Varietal Selection (PVS):*** Introduced for the first time in SSA, PVS has revolutionized the scientist-farmer interaction across SSA and unleashed a wave of NERICA adoption. This is being further advanced through the African Rice Initiative (ARI) coordinated by the Center to disseminate NERICA varieties and complementary technologies across SSA. Participatory Varietal Selection for Research and for Extension (PVS-R and PVS-E) is a means of involving farmers at all levels of the development process. PVS enhances capacity building and ownership of products, and reduces the time involved in the variety release process by up to 10 years. PVS has been quite instrumental in the release of varieties in several African countries, including Benin, Burkina Faso, Côte d'Ivoire, Guinea,

Mali, Nigeria and Togo. Participatory variety selection is the major vehicle enabling the speedy introduction of improved varieties that meet the requirements of resource-poor farmers. Instead of taking 12 years to introduce a new variety under conventional breeding, PVS new lines reach the farmer – for evaluation – in five years and farmers have a major input into the selection of lines released. Progress was made in the supply of sufficient NERICA seed to support large-scale dissemination.

- ***Community-based Seed multiplication Scheme (CBSS):*** CBSS ensures that seed multiplication is devolved to farmers and producers thereby bringing farmers closer to researchers and extension agents. CBSS has been instrumental in the production of seed used in the PVS trials.
- ***Participatory Adaptation and Diffusion of technologies for rice-based Systems (PADS):*** implementation of the PADS project has brought thousands of farmers into contact with WARDA's NERICA varieties for use in low-input rainfed systems through participatory field experimentation, demonstrations and a seed multiplication program in Côte d'Ivoire, Guinea, Ghana, Mali and The Gambia. NERICA varieties have been especially appreciated by farmers because of their short growing cycle (80 to 100 days), which allows the crop to be harvested during the hungry season and reduces labor demand compared to the local rice varieties.
- ***PADS used the CBSS-approach to stimulate farmers in taking the lead in seed supply:*** PVS and CBSS involved more than 20,000 farmers and more than 20 tonnes of NERICA seed were produced and distributed. Local networks and communication channels in which NGOs played a crucial role have been used to promote the new seed. PADS also developed extension materials such as technical fact sheets and leaflets on improved rice varieties, weeds and fertilizer management, the use of bio-pesticides, improved parboiling technology, etc.

The implementation of PADS led to the use of a methodological process-approach for Participatory Learning and Action Research (PLAR) involving farmers, extension, NGOs and research in order to improve participatory experimentation and fine-tuning of technical options by the farmers themselves; regular field visits; improved observation skills of farmers to allow improved analysis and decision-making; discovery of agro-ecological principles in a social learning setting; sharing basic knowledge of technologies among farmers; and analyzing financial and risk implications of new practices by farmers themselves. PLAR has enabled the possibility of a Rural Knowledge Center where the interested farmers can be trained as facilitators and can (partly) take over the role of the governmental (or NGO) facilitators. The idea is that the farmers-facilitators disseminate findings and learning tools/methods to neighboring lowland sites through farmer-to-farmer learning on demand.

The role of ROCARIZ

Contributor: Lawrence Narteh

The partnership model that has been most acclaimed by WARDA's national partners is the task force mechanism of the ROCARIZ (*Réseau ouest et centre africain du riz*/West and Central Africa Rice Research Network) rice network, which has played a central role in the development of the lowland NERICA varieties. It facilitated the shuttle-breeding approach to accelerate the selection process and achieve wide adaptability of the lowland NERICA varieties. Thanks to the task force model, the Center has reinforced SSA's capacity for rice research. The roots of ROCARIZ can be traced to 1991 under a different name and structure known as the WARDA Task Forces.

WARDA recognizes that there are too many rice production constraints to enable either it or the National Agricultural Research

and Extension Systems (NARES) as individual entities to handle single-handedly the research agenda for developing, evaluating and transferring technologies for rice-based cropping systems. WARDA requires the collaboration of NARES to ensure significant impact. As an association of West African states it has privileged access to NARES, and a particular responsibility to serve their respective countries. To this end, WARDA and NARES scientists have pooled their scientific skills to acquire the strength to address the most important research issues through network and partnership arrangements. ROCARIZ was instrumental in the development of the NERICA rice varieties for Africa when its members took an active part in the crossing of *Oryza glaberrima* × *O sativa* and also participated in the on-farm testing and release of the new varieties.

ROCARIZ contributed significantly to closer and increased research collaboration between WARDA and NARS scientists and among the NARS. In addition, it has boosted capacity building through the devolution of responsibility for research activities to NARS and helped increase the capacity of NARS to generate project proposals and scientific publications.

The role of INGER-Africa

Contributors: Eklou A. Somado and Robert G. Guei

The African wing of the International Network for Genetic Evaluation of Rice (INGER-Africa) is the largest rice testing network in Africa. Operated by the Africa Rice Center (WARDA) since 1994, it has the mission to ensure wide and rapid dissemination of rice germplasm in sub-Saharan Africa. This network was created to meet the needs of most national rice research programmes in SSA, which have limited access to diverse genetic materials and rely on international centers to broaden their crop genetic bases.

INGER-Africa has catalyzed regional efforts in public-sector rice research, resulting in the release of about 200 improved rice varieties over the past 25 years in West Africa alone. An impact study found that the producers' surplus gains from these improved varieties were worth about USD 360 million in 1998 alone and that, without them, the West African regional balance-of-payment deficit for rice imports in 1998 would have been 40% higher. Additional 650,000 hectares of farmland would have to be under rice cultivation to maintain consumption levels at their current standard (Dalton and Guei, 2003).

WARDA has strengthened its germplasm distribution, regional evaluation and utilization activities across sub-Saharan Africa in recent years. Improved rice germplasm have been multiplied, processed and distributed – free of charge – through INGER-Africa nurseries for further evaluation under local conditions and utilization by national rice improvement programs in SSA.

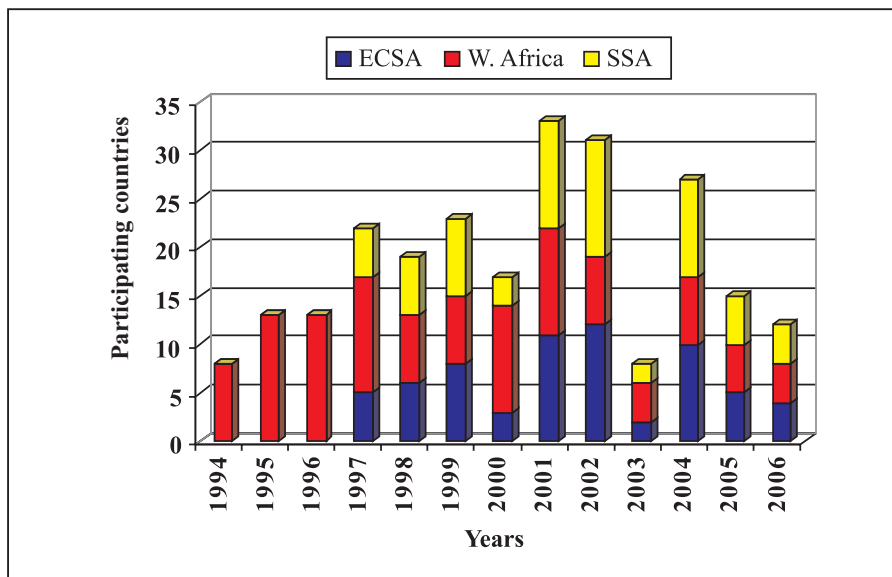


Figure 7. Number of participating countries in INGER-Africa from 1994 to 2006

Between 1997 and 2006 INGER-Africa responded to the demand for interspecific rice varieties (*O. glaberrima* × *O. sativa*) from 29 countries in SSA, including 14 in West Africa (WA) and 15 in East, Central and Southern Africa (ECSA) (Figure 7) by multiplying, purifying and dispatching seeds of these improved materials initially received from WARDA’s breeders.

Interspecific germplasm (*O. glaberrima* × *O. sativa*) distributed by INGER-Africa in SSA, 1997–2006

Based upon requests from NARS, INGER-Africa’s nurseries were assembled for the rainfed upland and the rainfed lowland/irrigated lowland systems (Figure 8).

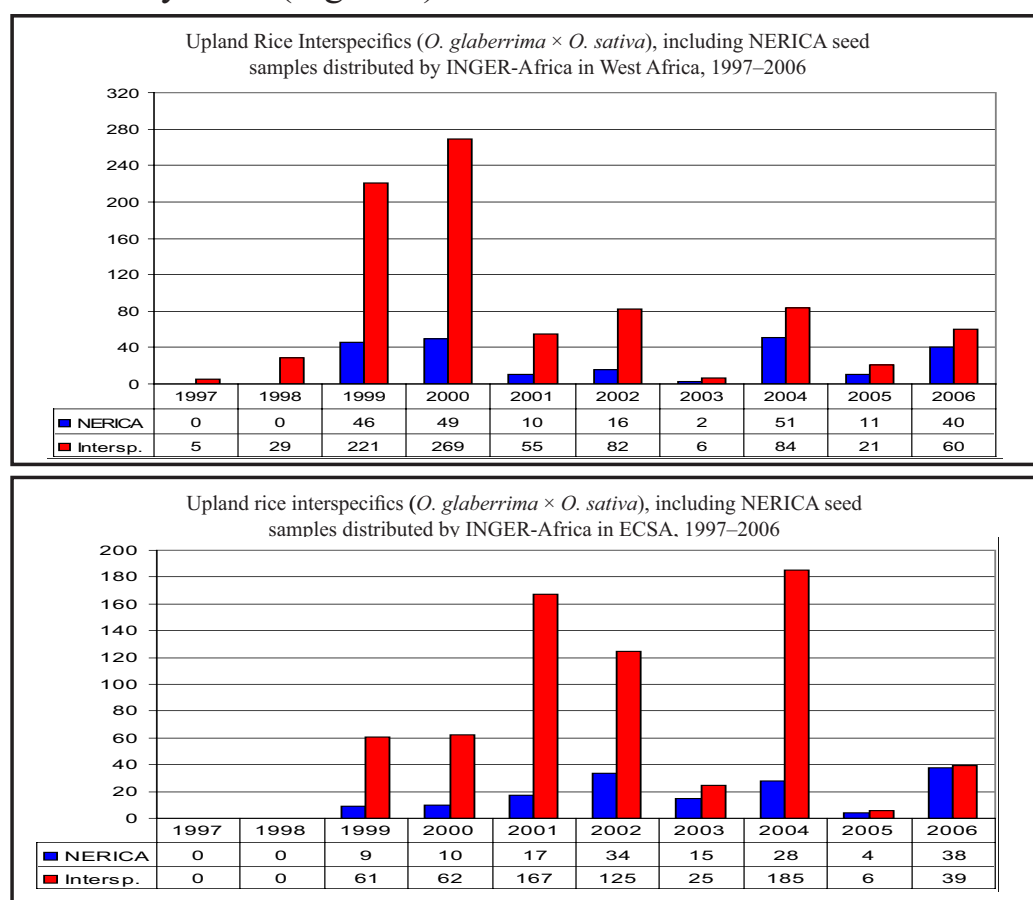


Figure 8. Rainfed upland and lowland/irrigated rice interspecifics (*O. glaberrima* × *O. sativa*), including NERICA seed samples distributed by INGER-Africa in sub-Saharan Africa, 1997–2006

A total of 832 seed samples of interspecific lines, including 225 of NERICA varieties, were dispatched as upland nurseries for evaluation by scientists in WA, while 670 samples, of which 155 were upland NERICA varieties, were sent to ECSA for the same purpose (Tables 8–9). Between 2003 and 2006, Japan, Belgium, Germany and the USA requested and were supplied with 88 seed samples of interspecific lines, of which 62 samples were upland NERICA varieties.

It was only in 2005–2006, subsequent to the development and naming of these interspecific lines, that the requests for and distribution of the lowland-irrigated NERICA varieties took off. During that period a total of 17 seed samples were dispatched to Guinea, Liberia and Sierra Leone in WA while 186 were sent upon request to Ethiopia, Tanzania and the Central African Republic in ECSA. Also, upon request, Japan was supplied with 62 samples of the lowland-irrigated NERICA–L 32 variety.

The 29 SSA countries receiving interspecific varieties seed samples during the period under review included 14 countries in WA (Benin, Burkina Faso, Côte d’Ivoire, The Gambia, Liberia, Senegal, Sierra Leone, Niger, Nigeria, Mali, Ghana, Guinea, Guinea-Bissau and Togo) and 15 in ECSA (Burundi, Cameroon, Chad, Central African Republic, Democratic Republic of Congo, Congo-Brazzaville, Rwanda, Madagascar, Ethiopia, Kenya, Tanzania, Uganda, Sudan, Zimbabwe and Mozambique). See Tables 9 and 10.

Table 9. Number of lines of upland rice interspecifics (*O. glaberrima* × *O. sativa*), including NERICA (indicated in parentheses), evaluated each year per country by INGER-Africa in West Africa, 1997-2006

West Africa	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	TOTAL	Upland NERICA variety
Benin	0	3	0	8 (4)	0	0	0	3(3)	0	5(3)	19(10)	NERICA2, NERICA 4, NERICA5, NERICA6, NERICA7, NERICA8, NERICA11
Burkina Faso	0	0	42 (8)	5 (2)	4(1)	0	0	0	0	0	51(11)	NERICA1, NERICA2, NERICA4, NERICA6, NERICA7
Côte d'Ivoire	0	0	0	21(1)	0	0	0	7	0	13(11)	41(12)	NERICA1, NERICA2, NERICA3, NERICA4, NERICA5, NERICA6, NERICA7
Gambia	0	0	21 (4)	4(3)	4(2)	0	0	0	0	0	29(9)	NERICA1, NERICA4, NERICA6, NERICA 7
Ghana	0	9	46 (8)	34 (2)	4(2)	11(6)	2	23(23)	0	0	129(41)	NERICA1, NERICA2, NERICA 3, NERICA4, NERICA5, NERICA6, NERICA 7
Guinea	0	1	24 (6)	2(2)	0	0	0	1(1)	11(9)	11(9)	50(27)	NERICA1, NERICA 2, NERICA 4, NERICA7, NERICA8, NERICA9, NERICA12, NERICA13, NERICA14, NERICA15, NERICA16, NERICA17, NERICA 18
Guinea Bissau	0	0	0	47(7)	0	8(1)	0	0	10(2)	0	65(10)	NERICA1, NERICA2, NERICA4, NERICA5, NERICA6
Liberia	0	0	10 (3)	0	0	0	0	0	0	5(4)	15(7)	NERICA1, NERICA2, NERICA4, NERICA5, NERICA7
Mali	0	0	0	45(10)	12	0	4(2)	32(13)	0	0	93(25)	NERICA1, NERICA2, NERICA3, NERICA4, NERICA5, NERICA6, NERICA 7
Niger	0	0	0	0	6(1)	2(1)	0	0	0	2(1)	10(3)	NERICA1, NERICA2, NERICA4, NERICA 6
Nigeria	0	3	48 (8)	47 (8)	0	0	0	4(4)	0	10(8)	112(28)	NERICA1, NERICA2, NERICA5, NERICA6, NERICA7, NERICA8, NERICA9, NERICA10
Sierra Leone	5	13	12 (3)	55(9)	24(4)	61(8)	0	7(7)	0	12(4)	189(35)	NERICA1, NERICA2, NERICA3, NERICA4, NERICA5, NERICA6, NERICA 7
Senegal	0	0	0	0	0	0	0	0	0	2	2	WAB 450-I-B-P-153-HB, WAB 450-I-B-P-33-HB (Interspecifics other than named NERICA)
Togo	0	0	20 (6)	1	0	0	0	0	0	0	20(6)	NERICA1, NERICA2, NERICA4, NERICA5, NERICA6, NERICA7
Total	5	29	221(46)	269(49)	55(10)	82(16)	6(2)	84(51)	21(11)	60(40)	832(225)	

Table 10. Number of lines of upland rice interspecifics (*O. glaberrima* × *O. sativa*), including NERICA lines (indicated in parentheses) evaluated each year per country by INGER-Africa in East, Central and Southern Africa, 1997–2006

ECSA	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total	Upland NERICA Variety Name
Burundi				7							7(0)	NERICA1 to NERICA 7
Cameroon									18(18)		18(18)	NERICA1 to NERICA 18
Congo					42(9)	13(7)	23(7)			101(23)	115(29)	NERICA1 to NERICA 7
Congo DR	11(1)		13(3)	30(7)	54	9(2)	20(14)			3(2)	50	NERICA1, NERICA 2, NERICA 4, NERICA 6, NERICA 7
Ethiopia					1(1)	4(1)	4(1)				53(12)	NERICA1, NERICA 2, NERICA 4, NERICA 6
Kenya	4		40(9)								2	WAB 450-11-1-P41-3-HB
Madagascar	2											WAB 450-1-B-P-23-HB (Interspecific lines other than named NERICA)
Central African Republic									6(4)		6(4)	NERICA1, NERICA 2, NERICA 4, NERICA 6, NERICA 7
Mozambique				34							34	NERICA1, NERICA 2, NERICA 4, NERICA 5, NERICA 6, NERICA 7
Rwanda					11	4(1)					13(1)	NERICA 6
Sudan	13(1)						29(7)				44(8)	NERICA1, NERICA 2, NERICA 3, NERICA 4, NERICA 5, NERICA 6, NERICA 7
Chad			20(6)	9(1)	30(9)	66(21)					125(31)	NERICA1, NERICA 2, NERICA 3, NERICA 4, NERICA 5, NERICA 6, NERICA 7
Tanzania							8(7)			18(18)	103(39)	NERICA1 to NERICA 18
Uganda			11(1)				29(7)				40(8)	NERICA1 to NERICA 7
Zimbabwe							7(7)				7(7)	NERICA1, NERICA 2, NERICA 3, NERICA 5, NERICA 6, NERICA 7
Total	61(9)	62(13)	167(17)	125(34)	25(15)	185(28)	6(4)	39(38)	670(158)			

The role of the African Rice Initiative (ARI)

Contributor: Inoussa Akintayo

While ROCARIZ is mainly a research network, ARI was created to deal with one of the major bottlenecks of rice production—the availability of quality seed. ARI covers the whole of SSA and maintains a presence in each participating country through a stakeholder platform. ARI has contributed to strengthening relationships between extension services and research institutions. It is a vehicle of dissemination for WARDA products from production and development to processing and marketing. Since ARI's inception in 2002, the following main achievements have been recorded:

- Seed availability is constantly addressed by the Coordination Unit. Table 11 provides a summary of foundation seed produced and distributed to several countries through ARI.

Table 11. Production and distribution of NERICA foundation seed by ARI Coordination Unit

Year	Seed produced (kg)			Seed distributed (kg)			Beneficiary countries
	BS ¹	FS ¹	Total	BS	FS	Total	
2003	75	350	425	65	350	415	Mali, Togo
2004	151	1 063	1 214	100	1 000	1 100	Burkina Faso, Mali, Togo, Nigeria
2005-06	1 474	14 102	15 576	1 400	13 900	15 300	Benin, Burkina Faso, DR Congo, Ethiopia, The Gambia, Ghana, Guinea, India, Kenya, Mali, Nigeria, Mozambique, Philippines, Sierra Leone, Tanzania, Togo, Uganda.
Cumulative Total	1 700	15 515	17 215	1 565	15 250	16 815	

¹BS: Breeder Seed; FS: Foundation Seed

- In order to increase adoption rate and boost production, ARI facilitated the introduction of more than 400 interspecific lines, including NERICAs, to farmers through PVS. By the end of 2005, 11 new NERICA varieties (NERICA8–NERICA18) were named, from which three were released. The newly-named materials are mainly extra-early (e.g. NERICA8 and NERICA9) at 80 days to maturity. ARI also contributed to the introduction and release of lowland NERICA lines; up to 60 have been named, from which five have already been released.
- ARI activities were initially restricted to pilot countries, but have been extended progressively to further countries. By 2005, NERICA lines had been tested in many countries in SSA (Figure 9). Forty six NERICA lines were adopted and 19 released in 17 countries, the number of varieties per country ranging from one to seven.

Area in SSA producing NERICA varieties

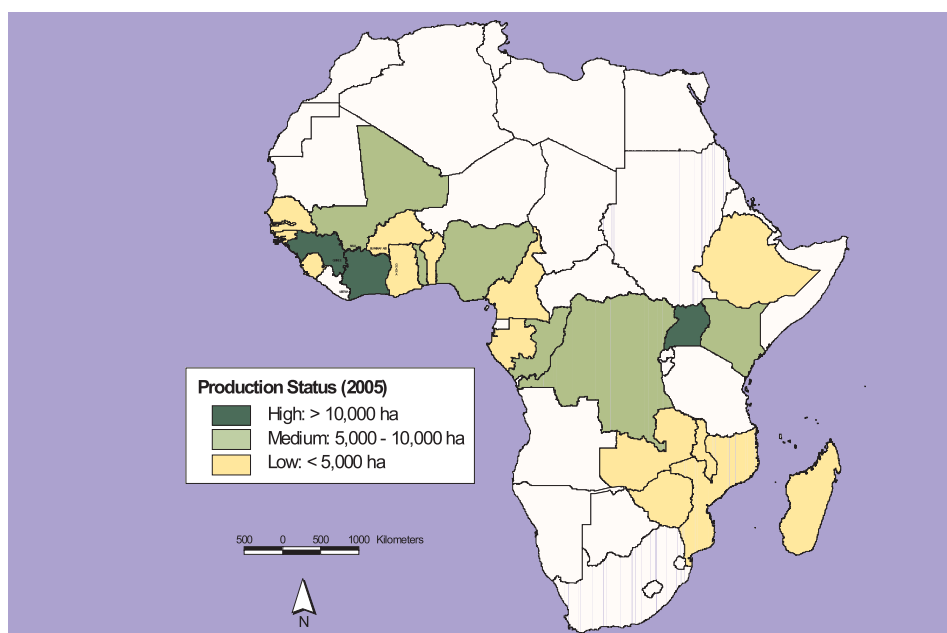


Figure 9. Area cultivated under NERICA varieties in 2005

NERICA rice varieties have been making headway in SSA. In 2006 it was estimated that NERICA varieties were planted on more than 200,000 hectares across Africa, including about 70,000 ha in Guinea and 15,000 ha in Uganda. Figure 9 illustrates the area grown to NERICA varieties in Africa in 2006. Figure 10 shows NERICA distribution in 2006

The NERICA dissemination effort is not intended to replace local varieties totally but to integrate NERICA varieties into the existing varietal portfolio of rice farmers, with complementary technologies, sound natural resource management practices and improved rice marketing and distribution systems.

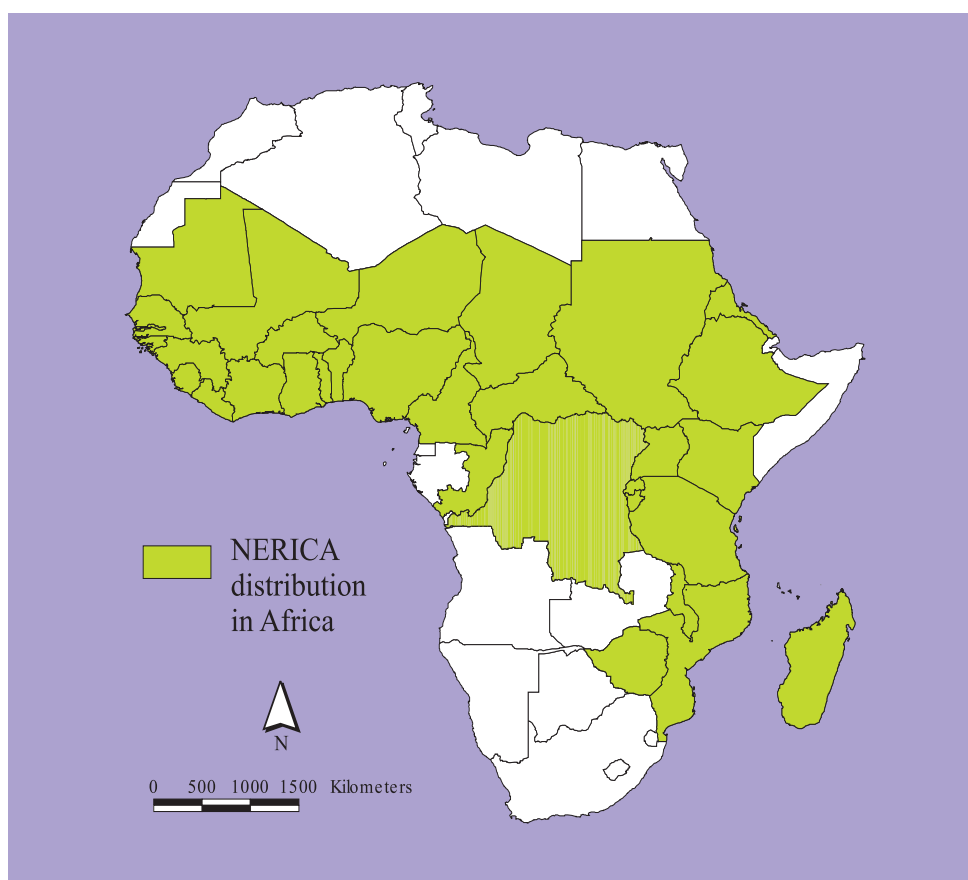


Figure 10. NERICA distribution in SSA (2006)

The role of PVS

Contributors: Howard Gridley and Moussa Sié

Farmers in the driving seat

The goal of PVS (participatory variety selection) is to transfer improved rice varieties to farmers efficiently in order to:

- reduce the time required to move varieties into farmers' fields;
- determine the varieties that farmers want to grow
- learn the traits that farmers value in varieties to assist breeding and selection
- determine if there are gender differences in varietal selection criteria

Research on PVS has revealed a gender-based varietal selection process whereby men and women farmers use different criteria to evaluate varieties. For instance, men gave importance to short growth duration and plant height, whereas women preferred traits such as good emergence, seedling vigor and droopy leaves that indicate weed competitiveness, since they are mostly involved in the sowing and weeding operations.

Research methodology

The NERICA varieties were introduced to rice farmers in Côte d'Ivoire in 1996 and Ghana, Togo Guinea in 1997, through Participatory Variety Trials (PVS), (WARDA, 1999). Farmers then started disseminating them through their informal channels. Seven NERICA varieties (NERICA1–NERICA7) intended for upland rice farming were being used by farmers in 2000.

PVS was chosen because it:

- shortens the time lag between varietal development and release
- accelerates the rate of adoption of promising rice varieties from WARDA

- obtains farmer criteria for choosing/adopting rice varieties and passes such information to researchers for further refinement of technology
- has efficient methodology – a 3-year program (Box 1)
- is a tool for efficient transfer of improved rice technologies to farmers

In the first year of PVS, WARDA and national scientists and local farmers identify centralized fields near villages, and plant ‘rice gardens’ with up to 60 upland varieties. The varieties range from traditional and popular *O. sativa* cultivars to NERICA developments, African *O. glaberrima* cultivars and local varieties as checks. Men and women farmers are invited to visit the fields as often as possible, but farmers are brought in groups for formal evaluation of the test entries at three key stages (maximum tillering, maturity and post-harvest). For the first two visits, farmers compare agronomic traits, including weed competitiveness, growth rate, height, panicle type and growth cycle, while the third visit focuses on grain quality attributes such as size, shape, shattering, ease of threshing and husking and palatability. Each farmer’s varietal selection and the criteria for selection are recorded and later analyzed.

In the second year, each farmer receives as many as six of the varieties, which he or she selected as favorites in the first year, to grow on his or her own farm. Thus, new genetic diversity enters the communities. PVS observers, who may comprise breeders and/or technicians from NGOs and Extension Services, visit participating farmers’ fields to record performance and farmer appreciation of the selected varieties. At the end of the year, farmers evaluate threshability and palatability to provide a full view of the strengths and weaknesses of the selected varieties.

For the third year, farmers are asked to pay for seeds of the varieties they select as evidence of the value they place on them. Thus, in three years, PVS-Research (PVS-R) allows the farmers to select

varieties with specific adaptation and preferred plant type and grain quality characters. These, in turn, can be integrated into the breeding programmes to tailor new varieties for farmers.

Participatory varietal selection

Year 1: Rice garden: Farmers are exposed to a range of promising cultivars and make selections.

Year 2: Farmers plant selections alongside local varieties.

Year 3: Farmers verify for a further year variety preferences–selection criteria.



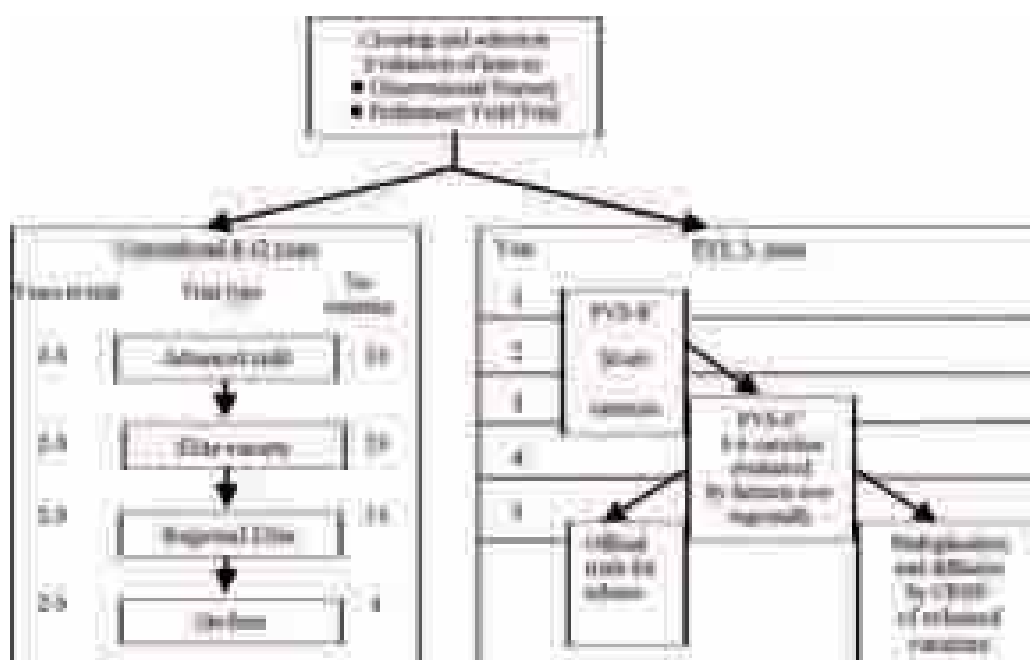
Box 1. PVS methodology – a 3-year program

Advantages of PVS methodology over the conventional scheme

Conventionally, it takes at least 12 years to put varieties in farmers' hands and, even then, farmers and consumers may not appreciate the varieties selected. A PVS extension (PVS-E) phase has recently been introduced to complement PVS-R and accelerate dissemination and official release. Four to six of the more commonly-selected varieties in the second year of PVS-R in an ecoregion are disseminated widely to farmers within the region for evaluation in the third year. After two years of PVS-E, the more-preferred of these varieties are enrolled in multi-location trials to generate data for official release.

Simultaneously, these varieties enter community-based seed systems (CBSS) for multiplication to ensure adequate seed supplies for rapid dissemination of the varieties once they are officially approved for release. PVS research is a novel applied and adaptive research mechanism that favors farmers playing an active role in product

development and spread. It has assisted in the early and broad dissemination and adoption of promising lines, including NERICA varieties, by NARES, development agencies and farmers in WCA. WARDA introduced PVS into Côte d'Ivoire in 1996 and farmers liked the concept of sharing responsibilities for rice research because they were able to select varieties that met their needs. Encouraged by the results, WARDA extended it to all 17 WARDA member countries by 1999. Regionally, more than 3500 farmers in WCA participated in the PVS and about 5000 farmers were exposed to improved upland rice varieties through PVS in 2000.



¹ PVS-R and -E: PVS Research and Extension, respectively. ² CBSS: Community-based Seed System.

Figure 11. Representation of relative time scales for conventional variety development and PVS to deliver new varieties to farmers

WARDA has been providing varieties for participatory varietal selection over the last 10 years. Table 12 summarizes farmers' selection criteria for adoption of NERICA rice varieties in different countries in SSA.

MOLECULAR CHARACTERISATION OF NERICA LINES

*Contributors: M-N Ndjiondjop, K Semagn, M Cissoko,
MP Jones and S McCouch*

Unit 1 – Molecular profiling of NERICA lines

As mentioned throughout this compendium, NERICA rices are interspecific inbred progeny derived from crosses between *Oryza sativa* × *O. glaberrima*. This chapter is a report of a study that evaluated 70 BC₂ interspecific lines developed by crossing a tropical japonica variety (WAB 56-104) as the recurrent parent to an *O. glaberrima* variety (CG 14) as the donor parent, followed by the use of anther culture to derive doubled haploids (DH) (26 lines) or eight generations of inbreeding to fix the lines (44 lines). Seven of these BC₂-derived inbred lines have been released as NERICA1–NERICA7. This study examined the relative contribution of each parent and the extent of genetic differences among these 70 sister lines using 130 well-distributed microsatellite markers, which cover 1725 cM of the rice genome. The average proportion of *O. sativa*-recurrent parent genome was 87.4%, while the observed average proportion of *O. glaberrima* donor genome was 6.3%. Non-parental alleles were detected in 83% of the lines but the overall average was 2.2%. Lines that had undergone eight generations of inbreeding in the field contained significantly more non-parental alleles (av. 2.7%) compared to the DH lines (av. 1.3%) that were developed from BC₂ anthers. Using both cluster and principal component analyses, two major groups were detected in these materials. The NERICA varieties (NERICA1 to NERICA7) clustered in one group while the remaining 63 lines clustered in another group, suggesting that the second group may offer significant opportunities for further selection and variety development.

Table 13. Summary of the proportion of genome for 70 NERICA varieties using 130 SSRs

		CG 14	WAB56-104	Heterogenous	Missing	Non parental
All 70 lines	Minimum	0.9	79.0	0.0	0.0	0.0
	Maximum	12.1	94.4	3.4	13.6	5.5
	Mean	6.3	87.4	0.4	3.7	2.2
7 NERICA lines	Mean	8.2	88.2	0.2	0.3	3.0
Other 63 lines	Mean	6.0	87.4	0.4	4.1	2.1
DHs n = 26)	Mean	5.5	87.5	0.5	5.2	1.3
Pedigree lines (n = 44)	Mean	6.7	87.4	0.4	2.8	2.7

Unit 2 – Microsatellites and agronomic traits for assessing genetic relationships among 18 NERICA varieties

Genetic differences and patterns of relationship among the first 18 NERICAs are largely unknown. A total of 102 polymorphic microsatellite markers were used to genotype 18 NERICA varieties. Subsets of seven NERICA varieties (NERICA1 to 7) were further characterized for 10 agronomic traits. The microsatellite data revealed no genetic difference between NERICA8 and 9. The absence of genetic distance and identical SSR haplotype distribution (banding pattern) observed between NERICA8 and 9 is highly likely to be due to lack of molecular difference at the DNA level but the possibility for seed admixture remains to be explored. This study, however, revealed the presence of a wide range of genetic differences among all other NERICA varieties, with the greatest being between NERICA6 and 17. Cluster and principal component analyses of the SSR data revealed distinct separation of NERICA1 to 7 from NERICA8 to 18.

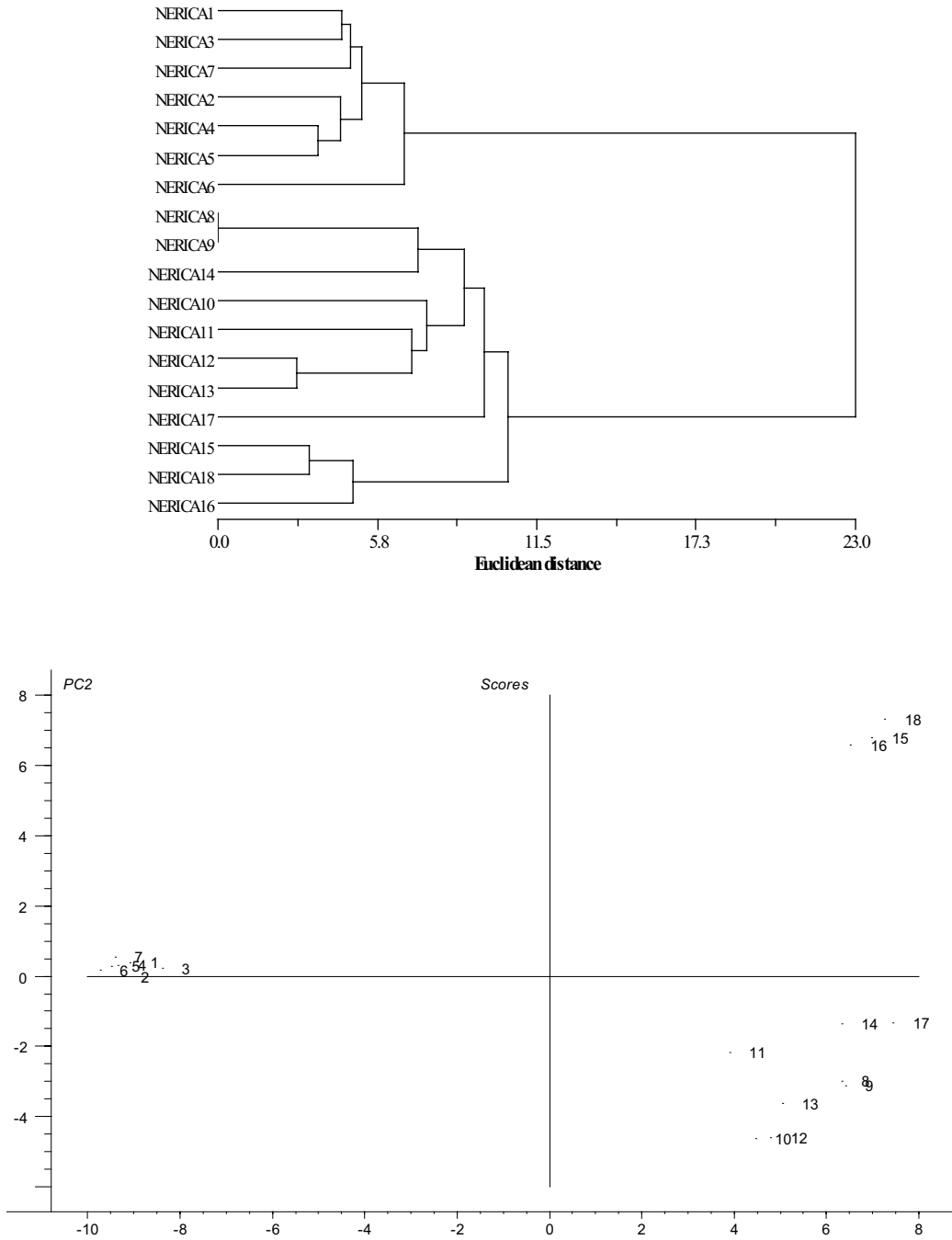


Figure 12. Cluster and principal component (PC) analyses performed using 104 SSR markers: UPGMA phenogram of 18 NERICA varieties based on Euclidean distance matrix, and score plot of NERICAs 1 to 18 from PC analysis. PC1 and PC2 explained 57% and 13%, respectively; numbers in the plot correspond to NERICA1 to 18.

Unit 3 – Molecular profiling of upland NERICA

Background information

The study reported above (Module 4/Unit 2) on the patterns of variation and genetic relationships among the named NERICA1 to NERICA18 concluded there was (i) a lack of genetic difference between NERICA8 and 9, (ii) a relatively wide range of genetic variability among all NERICAs, except NERICA8 and NERICA9, and (iii) a distinct pattern of variation that clustered NERICA1–7 in one group and NERICA8–18 in another (Semagn *et al.*, 2006).

However, the proportion and distribution of *O. glaberrima* introgressions in the larger collection of 70 sibling lines which are of great interest for future breeding efforts were not investigated.

It is noteworthy that NERICA is an extended family of several hundred interspecific progenies, of which 18 have been named by WARDA and released in various African countries.

The following section highlights the outcome of a study that analyzed 70 introgression lines to determine (i) the extent and map position of introgressions from *O. glaberrima*, (ii) the extent of heterozygous loci and non-parental alleles contained in the interspecific inbred lines, and (iii) the genetic relationships among the lines, with particular interest in evaluating the potential breeding value of the lines that have not been released as varieties.

The 70 interspecific lines (Table 14) were developed by crossing WAB 56-104 (*O. sativa* japonica), as the recurrent parent and CG 14 (*O. glaberrima*) as the donor parent. Twenty six of the lines were developed as double haploids (DH) derived from BC₂F₁ plants using anther culture (Guiderdoni *et al.*, 1992). The rapid genetic fixation achieved in the DH lines is expected to retain blocks of genes that would have been lost through conventional inbreeding (due to

sterility factors) and artificial selection (Jones *et al.*, 1997b). The remaining 44 samples were BC₂F₈ lines developed using pedigree selection (Jones *et al.*, 1997b). All 70 lines in this study had gone through two generations of backcrossing followed by either eight generations of selfing or doubling the haploid chromosome numbers and all behaved as inbred introgression lines.

Table 14. Pedigree and donor genome coverage (introgression) of 70 lines developed from WAB 56-104 as recurrent parent and CG 14 as donor parent.

Pedigree	Name or number	Introgression (%)	Pedigree	Name or number	Introgression (%)
WAB450-I-B-P-20-HB	NERICA7	7.3	WAB450-B-16A2.5	36	5.4
WAB450-I-B-P-38-HB	NERICA1	6.7	WAB450-B-16A2.10	37	6.2
WAB450-I-B-P-28-HB	NERICA3	3.4	WAB450-24-3-P3-1-HB	38	6.6
WAB450-I-B-P-138-HB	4	11.4	WAB450-B-18A2.4	39	5.7
WAB450-I-B-P-147-HB	5	5.2	WAB450-B-19A2.5	40	5.2
WAB450-12-2-BL1-DV5	6	5.2	WAB450-B-18A2.6	41	2.5
WAB450-I-B-P-135-HB	7	5.3	WAB450-B-3A1.2	42	8.3
WAB450-I-B-P105-HB	8	6.6	WAB450-4-1-A22	43	7.0
WAB450-I-B-P-91-HB	NERICA4	7.5	WAB450-B-19A3.1	44	7.4
WAB450-I-B-P-160-HB	NERICA6	12.1	WAB450-I-B-P-129-HB	45	6.4
WAB450-11-1-P31-1-HB	NERICA2	9.5	WAB450-I-B-P-82-2-1	46	7.3
WAB450-I-B-P-33-HB	12	6.3	WAB450-I-B-P-72-3-1	47	6.5
WAB450-11-1-1-P31-HB	NERICA5	11.0	WAB450-I-B-P-6-1-1	48	10.9
WAB450-24-3-2-P18-HB	14	10.2	WAB450-I-B-P-157-1-1	49	2.9
WAB450-11-1-3-P40-HB	15	7.4	WAB450-I-B-P-22-HB	50	8.0
WAB450-I-B-P-32-HB	16	8.1	WAB450-I-B-P-65-1-1	51	8.4
WAB450-12-2-BL1-DV1	17	8.0	WAB450-I-B-P-106-HB	52	8.7
WAB450-I-B-P-153-HB	18	9.8	WAB450-I-B-P-62-HB	53	2.8
WAB450-11-1-P40-1-HB	19	6.2	WAB450-I-B-P-51-1-1	54	4.5
WAB450-24-3-4-P18-3-1	20	7.0	WAB450-4-1-A16	55	9.9
WAB450-I-B-P-133-HB	21	8.1	WAB450-4-1-A26	56	4.9
WAB450-I-B-P-163-2-1	22	5.3	WAB450-B-16A2.7	57	5.5
WAB450-5-1-BL1-DV6	23	7.2	WAB450-B-16A1.2	58	11.0
WAB450-I-B-P-157-2-1	24	6.6	WAB450-4-1-A6	59	3.8
WAB450-I-B-P-23-HB	25	5.1	WAB450-B-19A1.2	60	4.6
WAB450-I-B-P-24-HB	26	5.5	WAB450-B-16A1.8	61	5.6
WAB450-24-3-P3-1-HB	27	4.5	WAB450-B-19A2.8	62	4.9
WAB450-6-2-9-MB-HB	28	7.7	WAB450-B-19A1.9	63	5.4
WAB450-4-A9	29	1.7	WAB450-B-18A2.2	64	3.0
WAB450-B-19A1.8	30	1.1	WAB450-B-16A2.4	65	5.7
WAB450-B-18A2.8	31	9.2	WAB450-I-B-P-139-HB	66	2.0
WAB450-16A1.6	32	3.3	WAB450-I-B-P-550-HB	67	3.5
WAB450-B-16A1.4	33	5.4	WAB450-I-B-P-26-1-1	68	10.3
WAB450-B-1A1.1	34	2.2	WAB450-5-1-4-B-1-H2	69	0.9
WAB450-4-1A14	35	8.4	WAB450-I-B-P-2-2-1	70	0.9

The 26 lines in boldface were double haploids derived from BC₂F₁, while the remainder were BC₂F₈ lines developed using repeated selfing and pedigree selection.

Highlights

The relative contribution of each parent and the extent of genetic differences among the 70 sister lines was established using 130 well-distributed microsatellite markers which cover 1725 centiMorgans (cM) of the rice genome. The average proportion of *O. sativa*-recurrent parent genome was 87.4% (1,508 cM), while the observed average proportion of *O. glaberrima* donor genome was 6.3% (108 cM).

Non-parental alleles were detected in 83% of the lines and contributed an average of 38 cM per line (~2.2% of genomic DNA). Lines that had undergone eight generations of inbreeding in the field contained significantly more non-parental alleles (av. 2.7%) compared to the DH lines (av. 1.3%) that were developed from BC₂ anthers. Using both cluster and principal component analyses, two major groups were detected in these materials. The NERICA varieties (NERICA1 to 7) clustered in one group while the remaining 63 lines clustered in another group, suggesting that the second group may offer significant opportunities for further selection and variety development.

Polymorphism and parental genome coverage

An initial polymorphism survey was conducted using DNA from the two parents (WAB 56-104 and CG 14). One hundred and thirty of the 164 SSR primers (79.3 %) screened were polymorphic between the two parents. The number of polymorphic markers per chromosome varied from eight on chromosomes 7 and 12 to 15 on chromosome 1 (Figure 13), and the overall average was 10.8 polymorphic markers per chromosome. The 70 lines were then genotyped with the 130 polymorphic SSR markers. Introgressions were detected in all individuals and on all chromosomes. *O. sativa* alleles were detected at all 130 marker loci in one or more individuals but only 57 markers (43.8%) showed introgressions from *O. glaberrima*. When the data from the 130 markers were used to estimate the proportion

of each parental genome in the 70 individuals, *O. glaberrima* DNA represented from 0.9 to 12.1% of the genome (Table 13; Figure 14) while *O. sativa* represented between 79.0 to 94.4%. The average proportion of the genome containing *O. glaberrima* alleles in the 70 lines was 6.3% (108 of 1,725 centiMorgans while it was 87.4% (1507.9 of 1,725 cM) for the *O. sativa* parent. Heterozygosity was observed at 19 marker loci in a total of 28 lines (40%). The frequency of heterozygosity ranged from 0.3 to 3.4 loci/line, and the average was only 0.4 per line.

Non-parental alleles were detected at 20 SSR loci (15.4%) in one or more of the 58 lines (82.9%). The frequency of non-parental alleles among the 58 lines varied from 0.4 to 5.5% non-parental alleles/line, with an average of 2.7%. When the genomic composition of the 44 lines developed through pedigree selection was compared with those of the 26 double haploids, there was significantly higher ($p < 0.05$) representation of *O. glaberrima* introgressions in the pedigree lines (6.7%) than in the double haploids (5.5%), but the proportion of recurrent parent (*O. sativa*) genome remained identical (87.4%). More significantly ($p < 0.001$), the number of loci containing non-parental alleles was twice as high in the pedigree lines (2.7%) compared to the double haploids (1.3%). The mean proportion of loci showing introgression of *O. glaberrima* in the seven NERICA varieties (NERICA1 to NERICA7) was 8.2%, which is significantly ($p < 0.05$) higher than in the 63 sister lines (6.0%). However, the proportion of non-parental alleles and of recurrent parent genome in the seven NERICA varieties were not different from their sister lines.

The distribution of introgressions varied among the 12 rice chromosomes. The chromosomes with the fewest *O. glaberrima* alleles (25% of SSR loci) and those with the highest proportion of *O. glaberrima* alleles (87.5% of markers) were chromosomes 3 and 12, respectively. When the map distances (cM) between markers were considered as the basis for estimating the extent of *O. glaberrima*

introgressions on each chromosome, chromosome 3 had the smallest amount of introgressed DNA (2.5%) while chromosome 6 had the highest (21.5%), and the overall average size of introgressed DNA per chromosome was 7.5% (Figure 12). The proportion of recurrent parent (*O. sativa*) genome varied from 64.3% on chromosome 6 to 94.7% on chromosome 11. Eight of the 12 chromosomes (all except chromosomes 3, 5, 9 and 12) contained heterozygous loci and the average heterozygosity for the eight chromosomes varied from 0.2 to 1.5%. Non-parental alleles were also observed in eight of the 12 chromosomes (all except chromosomes 5, 7, 10 and 11). The highest proportion of non-parental alleles (5.2%) was observed on chromosome 6 where the average across all 70 lines was 1.4% of loci. The proportion of non-parental alleles across chromosomes showed a high negative correlation ($r = -0.72$) with the proportion of recurrent parent (WAB 56-104) genome.

Genetic relationships among lines

Cluster analysis using the simple matching coefficients derived from SSR markers produced two major groups, with six sub-groups observed in the dendrogram in Figure 15. The seven released NERICA varieties belong to one major group (group-1), with NERICA6 being the most genetically divergent. Principal component analysis (PCA) also revealed two major groups. As shown in Figure 12, a plot of PC1 (12%) and PC2 (7%) clearly separated the two groups in the same way as the dendrogram. There were two differences between the dendrogram and principal component analysis: (i) NERICA3 was intermediate between the two groups in the PCA while NERICA6 was the outlier in the dendrogram, and (ii) the six subgroups from the dendrogram were not evident in the PCA.

Since NERICA1–NERICA7 were selected for variety release from among the 70 lines developed from the same parents, this study compared the average introgression in these seven varieties (Figure 13) with those in other sister lines and found that the released

varieties contained significantly more *O. glaberrima* DNA than the other lines. Based on results from field evaluation for phenotypic traits and participatory varietal selection, the present study suggests that the presence of specific *glaberrima* introgressions is associated with superior performance in the field. This hypothesis, however, remains to be tested using QTL and association analysis to identify which specific segments of the *O. glaberrima* genome are associated with superior agronomic performance in the upland rice production system.

The seven NERICA varieties represented only one of the two major groups revealed both by the cluster and principal component analyses (Figures 15 and 16), suggesting that the other lines may provide an opportunity for selection and additional varietal development. The possibility for further selection and varietal development within group-2 will be highly dependent on the availability of reliable morpho-agronomic data from multi-location trials.

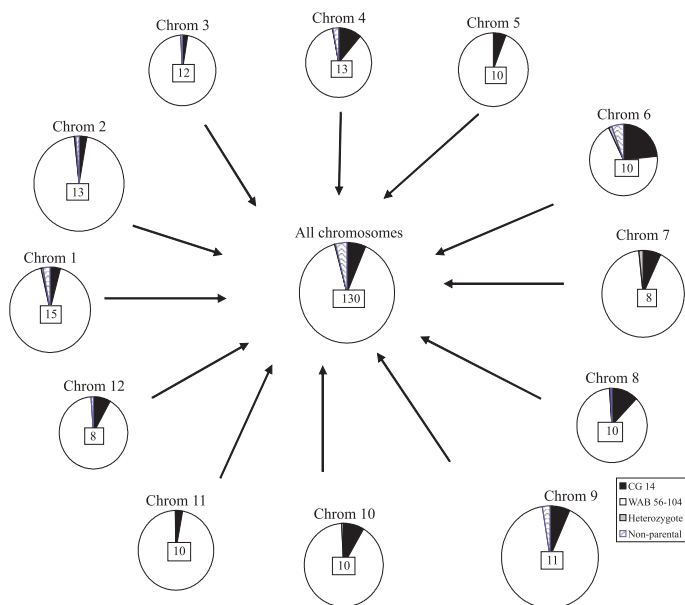


Figure 13. Pie charts for 12 rice chromosomes depicting the proportion of genome introgression in an interspecific rice population derived from CG 14 (donor) and WAB 56-104 (recurrent) parents. The pie charts were plotted from the graphical genotyping analyses outputs; the numbers in the center of the pies correspond to the number of SSR markers used in the study.

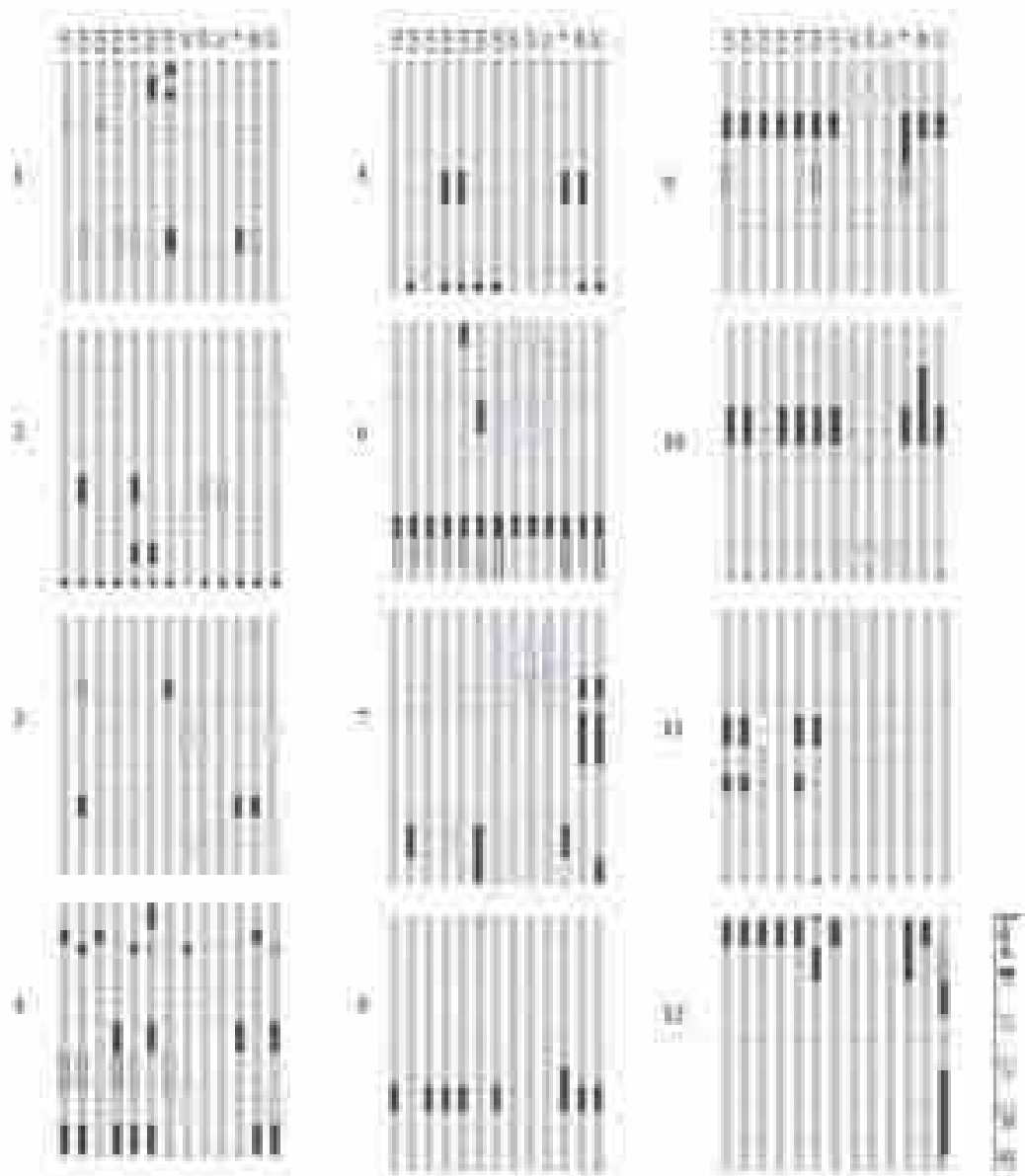


Figure 14a.

Graphical genotyping of the 13 interspecific lines using 130 microsatellite markers. Vertical bars represent the 12 chromosomes of rice, with chromosome number given on the left side of each bar.

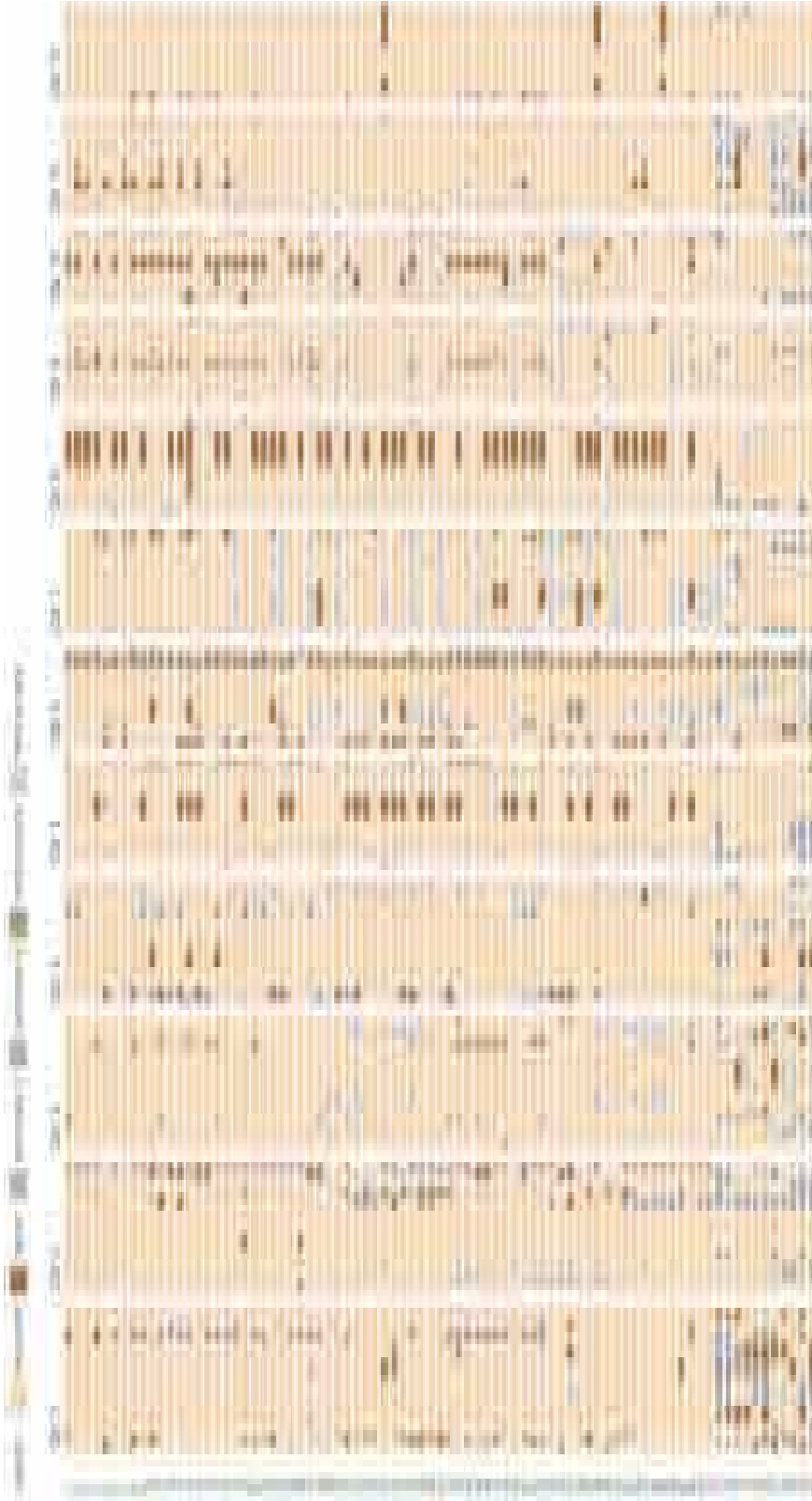


Figure 14b.

Graphical genotyping of the 81 interspecific lines using 130 microsatellite markers. Vertical bars represent the 12 chromosomes of rice, with chromosome number given on the left side of each bar.

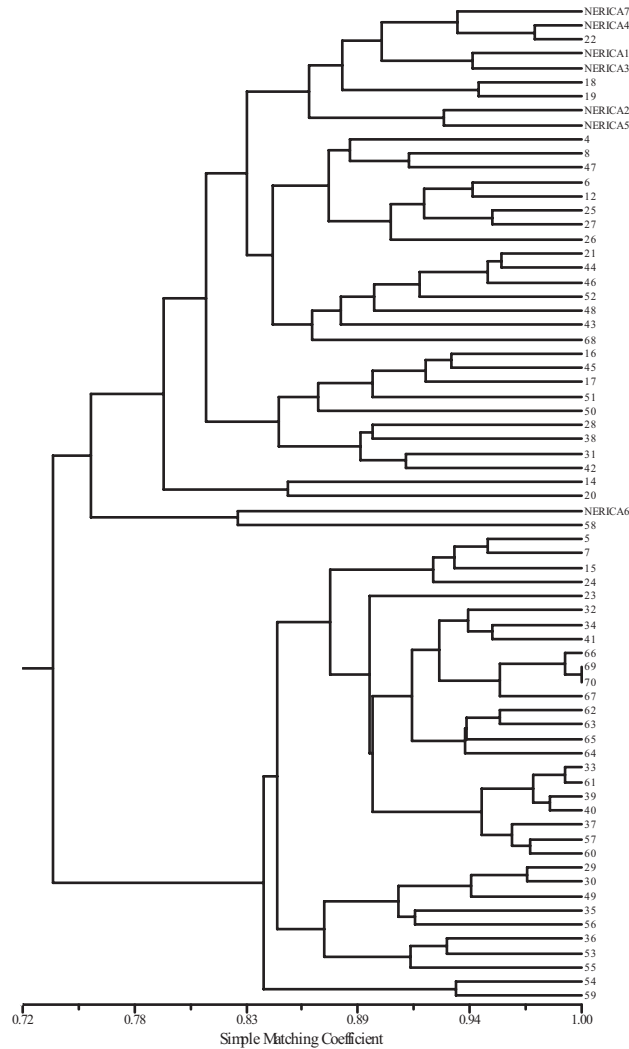


Figure 15. Dendrogram of the 70 interspecific lines using simple matching coefficients derived from 130 microsatellite markers. The lines were separated into two major groups and six subgroups although six other lines did not fit into the latter. Numbers correspond to the names as shown in Table 13. All lines within group-2, except the five lines indicated by arrows, contained introgression lower than the 6.3% average for the population.

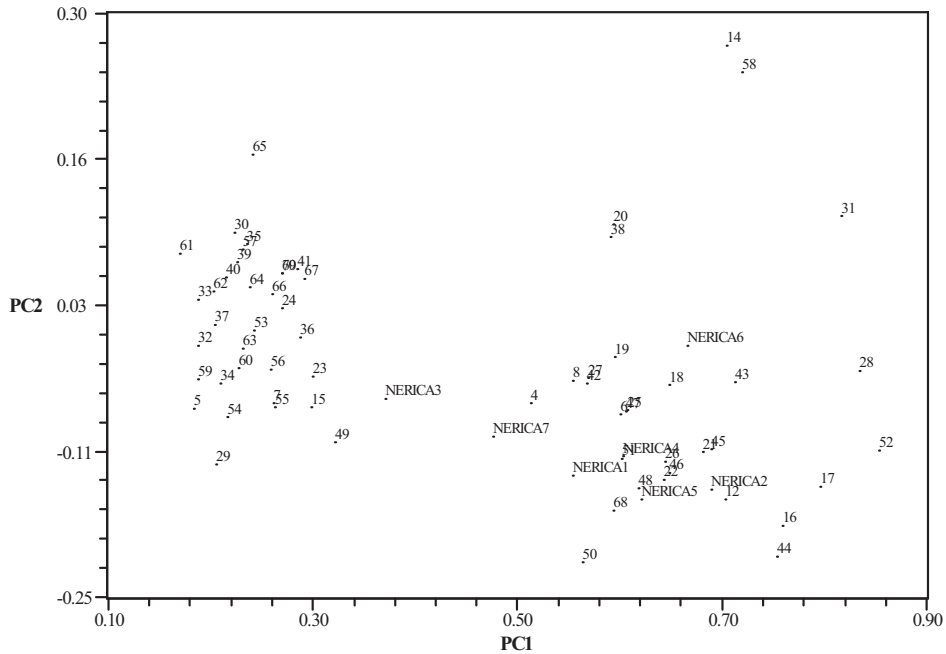


Figure 16. Score plot of the first two principal components from principal component analysis of the 70 interspecific lines genotyped with 130 microsatellite markers. Numbers in the plot correspond to the names as shown in Table 13.

Each chromosome is segmented by horizontal lines at the marker positions. Numbers on the top of the vertical bars refer to the 13 lines: N1 to N7 refers to NERICA1 to 7 (e.g. N1: NERICA1; N7: NERICA7); line number 30, 69 and 70 had the lowest introgression while line 4, 48 and 58 contained the highest introgression. Refer to Table 12 for pedigree for each line. Legend: A: CG 14 genome; B: WAB 56-104 genome; H: heterozygote; U: non-parental alleles; M: missing data.

DROUGHT SCREENING OF UPLAND NERICA VARIETIES

Contributors: Baboucarr Manneh and MN Ndjiondjop

Eleven NERICA varieties (N1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 12) as well as WAB56-104 and CG 14, the parents of NERICA1–7, were screened for drought tolerance together with 87 other rice genotypes that included *O. sativa* spp. *indica*, *O. sativa* spp. *japonica*, *O. glaberrima* and interspecifics (*O. sativa* × *O. glaberrima*), which were sourced from WARDA, CIAT and IRRI. The trial was conducted at Togoudo research station (Benin) in the dry season (December 2005–March 2006). In this trial, the drought screening protocol used involved imposing 21 days drought stress at 45 days after sowing (DAS), which coincides with the vegetative/reproductive phase of crop development. The trial was laid out as a split-plot design with irrigation regime as the main plot factor and genotype as the sub-plot factor. Two irrigation levels were used – full irrigation up to maturity and imposing 21 days drought stress starting 45 DAS. Recommended agronomic practices such as thinning, fertilizer application, weeding and spraying against pests and diseases were carried out. Soil water status at the trial site was measured in three 20 cm layers of soil from the surface to 60 cm depth.

The soil at the trial site is an Alfisol with a sandy texture (82–89%) from 0–50cm depth and hence has a low water-holding capacity. Soil moisture content in the top 20cm towards the end of drought stress (20th day of stress) was 2.61% in the stressed treatments and 4.5% in the fully irrigated treatment. Thus withholding irrigation for 21 days was sufficient to induce severe drought stress in the trial since the effective rooting depth of most rice varieties is the top 20cm of soil.

The first visual symptom of drought stress was leaf rolling, and severity of leaf rolling as well as leaf drying increased with duration of drought. Drought stress significantly ($P < 0.05$) reduced tiller number, leaf chlorophyll content (SPAD92), numbers and weights of fertile panicles and grain yield but increased leaf temperature and delayed flowering (Table 15). Flowering was delayed by 10 days in the stress treatment compared to the non-stressed treatment. Consequently, grain yield per plant was significantly reduced ($p < 0.05$) from a mean of 12.42 g in the fully irrigated treatment to 5.063 g in the stressed plot. The NERICAs exhibited a wide range of responses to drought stress. However, six (N3, 5, 7, 8, 9 and 12) out of the 11 NERICAs screened gave higher than the average yield under drought and there was no significant difference between yields of NERICA1, NERICA4 and the average yield under drought (Figure 17). NERICA2, NERICA6 and NERICA10 performed poorly under drought stress in this trial. However, further trials are being conducted to validate these preliminary results, and the findings will be incorporated in the next edition of this compendium.

Table 15. Effect of 21 days drought stress on morpho-physiological traits of upland NERICA lines with their parents WAB56-104 and CG14 at Togoudo research station, Benin.

Variety	Temp * 59		Tiller no. 92		SPAD 92		50% Flowering		FTPNO		FTPWT		Roll 67	Burn 67	Roll 80	Burn 80
	Irrig	Dry	Irrig	Dry	Irrig	Dry	Irrig	Dry	Irrig	Dry	Irrig	Dry	Dry	Dry	Dry	Dry
NERICA1	31	33	15	9	48	44	73	91	27	9	6.39	4.29	4	2	2	2
NERICA2	31	32	14	16	48	46	78	93	10	8	15.14	7.5	4	1	2	2
NERICA3	31	33	15	12	46	48	70	79	4	13	2.67	9.6	7	2	2	1
NERICA4	32	32	20	12	48	48	69	81	13	5	19.73	4.7	6	3	2	2
NERICA5	31	34	14	15	47	44	63	64	6	24	5.54	17.88	6	3	2	2
NERICA6	31	33	13	11	48	45	80	96	9	8	8.78	8.3	7	5	1	4
NERICA7	31	33	14	7	45	44	63	74	5	7	6.39	8.25	5	3	4	2
NERICA8	32	33	18	12	44	43	69	81	10	5	11.78	3.89	8	5	2	3
NERICA9	32	33	26	14	46	43	72	87	6	11	3.96	15.66	8	4	3	3
NERICA10	31	32	17	10	46	46	76	87	7	6	6.92	6.67	4	2	3	2
NERICA12	31	34	16	13	48	47	73	80	8	9	7.24	13.43	6	3	2	1
CG 14	31	33	43	39	39	38	59	64	20	3	7.96	2.19	9	4	4	3
WAB56-104	30	32	10	12	46	46	71	78	11	9	16.88	9.78	6	1	1	2
Mean	31	33	22	19	43.25	43.06	74	84	13	8	14.55	6.12	7	3	2	2
S.E.M.	0.1	0.1	0.36	0.35	0.13	0.13	1	1	1	1	0.35	0.33	1	1	1	1

a - Numbers following trait names indicate the DAS on which the trait was measured.

Note: Irrig – continuously irrigated; Dry – drought stressed; S.E.M.–standard error of the mean; Temp. – leaf temperature measured with infrared thermometer; SPAD – leaf chlorophyll content; 50% Flowering – no. of days from sowing to 50% flowering; FTPNO – no. of fertile panicles; FTPWT – fertile panicle weight; Roll – leaf rolling score under drought stress; Burn – leaf drying score under drought stress.

NERICA RICE CROP MANAGEMENT

*Contributors: Sylvester O. Oikeh, Sitapha Diatta,
Tatsushi Tsuboi and Tareke Berhe*

Background information

The timeliness and quality of land preparation are critical to rice production. NERICA varieties are no exception. Good soil tillage practices generally enhance efficient fertilizer-use, soil porosity and aeration and then have positive impacts during germination, seedling emergence and stand establishment stages of plant growth, in addition to weed control.

Unit 1 – Land selection and preparation

Land preparation for NERICA varieties can take the form of conventional tillage operations of ploughing and harrowing using tractor or animal traction. This is applicable mostly for medium- to large-scale farmers. Smallholder farmers, particularly in the humid forest agro-ecosystems, after clearing and burning the debris, use minimum tillage operation consisting of opening up of the spot to dibble in the NERICA seeds using a hand hoe.

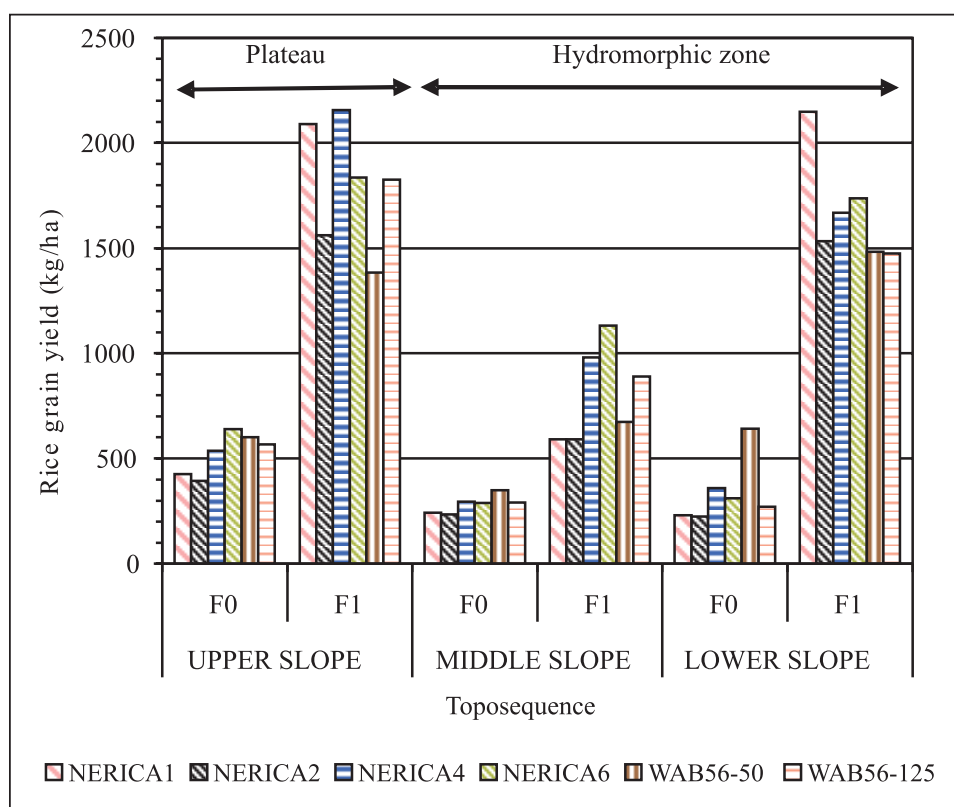
Unit 2 – Land selection: where to grow NERICA varieties?

The NERICA varieties are developed for the upland production systems. They can grow in any agro-ecosystem under upland conditions so long as there is enough moisture to sustain the crop throughout the growth period. Some of the NERICA varieties (NERICA6 for example) can be grown in the hydromorphic fringes. However, waterlogged soils are not appropriate.

NERICA varieties can grow on a variety of soils ranging from moderately drained to well drained soils. In West Africa most of the

soils in the upland rice production agro-ecology are sandy loams to sandy clays with pH ranging from 5.0 and 6.0. In the humid forest agro-ecosystem, where there are heavy losses of exchangeable bases due to excessive rainfall, the pH may range between 4.0 and 4.5.

NERICA varieties can grow at both low and relatively high altitudes. For example, NERICA4 has been shown to thrive in Ethiopia at 1,900 meters above sea level (masl) and matured within 130–140 days. NERICA1–4 have been grown at low altitude in the Wabe Shebelle river valley in Ethiopia and matured within 80–90 days.



Source: WARDA (2006) Joint Interspecific Hybridation Progress Report, p.96.

Figure 17. Grain yield (kg ha⁻¹) of NERICA lines and sativa along the toposequence with (F1) and without (F0) fertilizer application.

Unit 3 – Cropping calendar

In general, upland rice can grow in any environment with at least 15 to 20 mm of five-day rainfall during the growing cycle. During germination and early growth stages, 15 mm per five-day rainfall is sufficient. In environments where there are two distinct cropping seasons, it is important to establish the time to sow in each season based on the long term (15-year) daily rainfall pattern or actual trials on optimum sowing date.

In Uganda, East Africa, based on the long-term rainfall pattern, sowing dates of 20–25 February for the first season and August 24–28 for the second season crop were recommended for optimum NERICA production (Tuboi 2006, personal comm.)

In the monomodal rainfall savannah zone of Côte d'Ivoire, West Africa upland rice is sown in May–June while sowing in March–April (first season) and May–June (second season) is recommended in the bimodal rainfall forest zone (Becker and Diallo, 1992)

Unit 4 – Planting of NERICA varieties

Before planting NERICA varieties, it is important to conduct a germination test to establish the actual seed rates to use based on the viability of the seeds.

NERICA seed treatment prior to planting

The NERICA seeds may be treated with Apron Star 42 WS (thiamethoxam + difenoconazole + metalaxyl-m) at the rate of one sachet (10 g) per 1 kg of seed 2–3 days before planting. Other suitable seed treatments may be used according to availability and per the manufacturers' instructions.

In an environment where termites and nematodes pose serious threat to uniform emergence and crop establishment, it is recommended

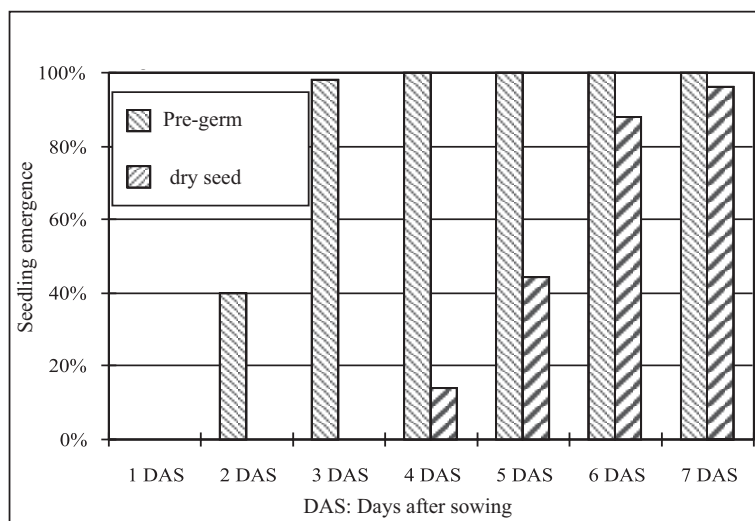
to incorporate carbofuran (Furadan) at the rate of 2.5 kg a.i. per hectare into the planting rows. To ensure uniform application, Furadan should be mixed with sand at a ratio of 1 part of Furadan to 4 parts of sand.

NERICA seed pre-germination prior to planting

To ensure uniform seedling emergence and good establishment, NERICA seeds can be pre-germinated before planting.



Figure 18. Seedling emergence of pre-germinated versus dry seed, in Namulonge, Uganda. (T. Tsuboi, unpublished data).



Unpublished data of T. Tsuboi in Uganda, East Africa, show that when dry NERICA seeds are sown directly, it takes five days for the seedlings to emerge. But for pre-germinated seeds (i.e. seeds soaked in water for 24 hrs and incubated for 48 hrs) it takes 2–3 days for the seedlings to emerge and the plants are uniformly established in the field (Figure 18).

NERICA seed dormancy breaking

Some NERICA varieties have showed dormancy characteristics (failure of mature seeds to germinate under favourable environmental conditions) inherited from their parent *O. glaberrima* (Guei *et al.*, 2002). In this case, particularly when using newly harvested seeds, seed dormancy would need to be broken to enhance uniform seedling emergence and establishment. This can be done by soaking the seeds for 16 to 24 hrs in 6 ml of concentrated nitric acid (69% HNO₃) per litre of water for every 1 kg of newly harvested seeds. After soaking, the acid solution is drained off and the seeds are sun-dried for 3–5 days to a moisture content of 14% and stored for sowing.

Unit 5 – Plant density

Uniform crop establishment and optimum plant densities are essential to optimize yields. The use of seed dressing, pre-germinated seeds and a sowing depth of 2 to 4 cm is recommended for uniform plant establishment.

When the seeds are viable (germination rate of more than 80%), seeding rate of 50–60 kg ha⁻¹ is recommended for dibble sowing and 80 kg ha⁻¹ for sowing by drilling. Five to seven seeds can be sown per stand and later thinned to 2–4 seedlings at 14 to 21 days old. If germination percentage is less than 80%, the seed rates should be increased accordingly. Note that only filled grains should be used for sowing. The empty grains should first be removed by floating in water.

In Benin (West Africa), a spacing of 20 cm × 20 cm with 4 plants per stand (1×10^6 plants ha⁻¹) for sowing by dibbling is recommended for NERICA cultivation.

In Uganda (East Africa), a spacing of 30 cm × 12.5 cm or 15 cm × 15 cm is recommended for sowing by dibbling. But when sowing is by drilling, a spacing of 30 cm × 1.7–2 cm or 25 cm × 2.2–2.4 cm is recommended.

A sowing depth of 2–4 cm is recommended for NERICA lines. Deep placement of seeds at more than 4 cm resulted in poor germination and delayed seedling growth (Tsuboi, unpublished data, 2005).

Unit 6 – Weed management in NERICA rice-based cropping systems

In West Africa, between 27 and 37% of the total labor invested in rice is taken up by weeding (WARDA, 1998). In the main rice growing ecologies – mainly the rainfed ecologies and those suitable for irrigated rice – weeds are the main constraints, reducing production by up to 40% and potentially causing total crop failure if left uncontrolled (WARDA, 1998). This constraint is well perceived by rice farmers. A survey conducted in Côte d'Ivoire by WARDA revealed that every single farmer identified weeds as a major problem in rice cultivation regardless of ecology.



The commonest weed species found in the rainfed upland ecology in West Africa include *Paspalum scrobiculatum*, *Euphorbia heterophylla*, *Chromola odorata*, *Oldenlandia herbacea*, *Tridax procumbens*, *Digitaria horizontalis*, *Tridax procumbens*, *Cyperus esculentus* and *Cyperus rotundus*. In the East, Central and Southern Africa (ECSA) country of Tanzania, *Ageratum conyzoides*, *Galinsoga pariflora*, *Clotalaria incana* and *Rottboellia cochinchinensis* are cited among the principal weed species encountered in the upland rice ecology.

Though *O. glaberrima* has been shown to be competitive against weeds (Johnson *et al.*, 1998; Fofana and Rauber, 2000), NERICA varieties cannot thrive in an unweeded field.



Hand-weeding regimes

When should I start weeding NERICA rice fields?

When weed pressure is minimal in the field, only one weeding within 15–21 days after sowing (DAS) is sufficient for NERICA rice plants to grow well. But when weed pressure is high, a second weeding at panicle initiation stage (about 42–50 DAS) is needed. Weed a third time if necessary.

However, hand weeding can be relatively ineffective, particularly in controlling many of the perennial weeds (e.g. *Cyperus* spp.) that have underground tubers and rhizomes from which they can rapidly re-establish. Therefore, integrated management of weeds involving the use of herbicides combined with hand weeding will be the most sustainable approach to managing weeds for NERICA production.

Chemical control

What is the recommended herbicide, its application rate and timing for NERICA varieties?

Any herbicide suitable for upland rice production can be used for NERICA varieties.

Pre-emergence herbicides: applied before the weeds emerge, they provide an extended period of weed control as they are used during land preparation before NERICA rice planting. Table 16 indicates general guidelines to some herbicides used in NERICA rice production.

Post-emergence herbicides: they are applied after emergence of rice and weeds, but preferably at the early growth stages of weeds (3–5 leaves).

Various types of weeds are associated with rice; therefore, the use of a combination of herbicides that kill different types of weeds is advised.

Table 16. Selected herbicides recommended for NERICA rice production

Herbicide formulation	Rate a.i. (kg ha ⁻¹) ¹	Time of application	Remarks
propanil + bentazon	1.0–3.0	Post-emergence	Formulated mixture. Apply 14–21 days after transplanting
propanil + 2.4D	3.0	Post-emergence	Apply 14–21 days after seeding or transplanting
propanil + thioben-carb	1.5–3.0	Post-emergence	Apply 14–21 days after seeding or transplanting
oxadiazon	0.6–1.25	Pre-emergence	For direct seeded (3 days after sowing)
butachlor	1.0–2.3	Pre-emergence	Apply within the first three days of sowing

¹Use higher rates when the weed pressure is high.

Use of legume fallows to control weeds in NERICA rice fields

Well-managed legume fallows provide opportunities to control weeds in the various agro-ecological zones in upland rice-based systems of West Africa. Fallow vegetation composed of legumes, including *Aeschynomene histrix*, *Stylosanthes guianensis*, *Canavalia ensiformis*, *Crotalaria anagyroides* and *Mucuna prurens* have been shown to control weeds when grown in sequence with upland rice in the savannah and forest agroecologies of Côte d'Ivoire, West Africa (Becker and Johnson, 1998).

SOIL FERTILITY AND NERICA RICE NUTRITION

*Contributors: Sylvester Oikeh, Sitapha Diatta and
Tatsushi Tsuboi*

Background information

Studies on soil characterization of rice ecologies in West Africa carried out by Africa Rice Center showed that in the upland production systems, the magnitude of nitrogen (N) deficiency increases from the humid forest to the semi-arid zone, whereas phosphorus (P) deficiency is highest in the humid forest but slight in the semi-arid (Oikeh *et al.*, 2006a). On soils developed from sandstones, all three macronutrients N, P and potassium (K) are deficient. Therefore, to optimize NERICA production in these soils will require the application of chemical fertilizers.

NERICA varieties have greater yield potential and respond strongly to the use of inputs such as fertilizers.

Agronomy and Integrated Soil Fertility Management

What is the optimum fertilizer rate required for the released NERICA varieties in the humid forest and savanna agroecosystems?

Can we identify rice varieties (NERICA and *Oryza sativa*) that are more efficient in the use of fertilizer?

Methodology

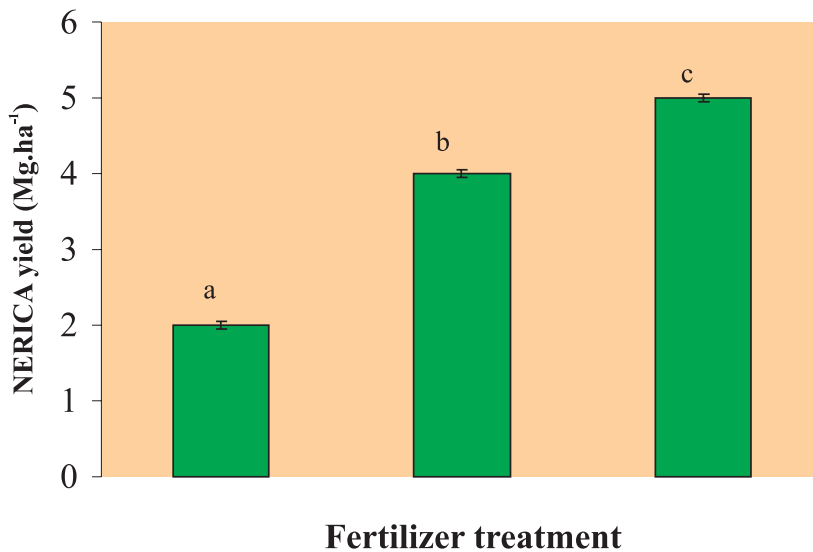
- NERICA1, 2, 4 and 6 were used
- Experimental site under fallow for 3 years
- Different combinations of NPK

Unit 1 – Rate and time of fertilizer application and NERICA response to nutrients

What is the optimum fertilizer rate required for the NERICA varieties under various input cropping systems?

The following fertilizer combinations are recommended for NERICA rice cropping systems in Benin. Please refer to country-specific recommendations for relevant site-specific fertilizer application.

- Combination of 60 kg N, 13 kg P and 25 kg K per ha (low to moderate input) has proved sufficient to double grain yield to *ca.* 4 tonnes per hectare as compared to zero fertilizer application.
- ~~Doubling the levels of N and P at the same level increases~~ Doubling the levels of N and P at the same level increases grain yield by 25% over a moderate NPK level.
- 120 kg N, 26 kg P and 25 kg K per ha (appropriate for high input farmers) generates 145% more grain yield compared to no NPK fertilizer application.



N60-P13-K25= 60 kg N, 13 kg P and 25 kg K per ha
 N120-P26-K25= 120 kg N, 26 kg P and 25 kg K per ha

Figure 19. NERICA response to fertilizer application in the humid forest zone of West Africa.

- Application of 120 kg N ha⁻¹ to NERICA varieties delays maturity by 4 days compared to zero-N fertilizer application.
- With the application of 120 kg N ha⁻¹, NERICA3 matures up to 5 days earlier than the other interspecifics, while the same dose of the same N-fertilizer prolongs the cycle of NERICA2 by about 3 days.
- The above information is important as the short growth cycle of the NERICA varieties is an important trait for drought escape and weed competitiveness, and may enable the farmers to diversify their cropping systems through intercropping or rotations.
- Oikeh *et al.*, (2006b) recommend the use of 60 kg N, 13 kg P and 25 kg K per ha for smallholder farmers with basal application of P and K at sowing and top dressing with one-third urea at the beginning of tillering, and the remaining two-thirds at about panicle initiation.

- Phosphorus is the second most important nutrient after N for rice production, because chemical fertilizers are not readily available nor affordable to smallholder farmers.

In West Africa, Rock-P is locally available in Mali and other neighbouring countries, including Burkina Faso, Mali, Niger, Nigeria, Senegal and Togo.

On the Ultisols (Ferralsols) of the humid forest agro-ecosystem of Côte d'Ivoire, West Africa, Diatta *et al.* (unpublished data) recommend a dose of 150 kg per hectare of rock-P from Mali applied every four years at NERICA rice planting.

Fertilizer requirements for other agro-ecosystems and the development of integrated soil fertility management packages for the different agro-ecosystems in West Africa are in progress.

In Uganda, East Africa, T. Tsuboi (personal communication, 2006) recommends for soils that are sufficient in K, the use of 55:23:0 NPK kg ha⁻¹ in the form of 50 kg ha⁻¹ di-ammonium phosphate [DAP, 18:46:0 (NP₂O₅K₂O)] at 15 to 20 days after germination (DAG, i.e. allowing 5 days between sowing and emergence), and 50 kg ha⁻¹ of urea (46% N) each at 15 to 25 DAS and 55 to 65 DAG. But for soils that are low in K, the use of 62:26:26 NPK in the form of 150 kg ha⁻¹ of NPK 17:17:17 and 15 to 20 DAS with additional top dressing with 30 kg ha⁻¹ urea at 15 to 20 DAG and 50 kg ha⁻¹ at 55 to 65 DAG are recommended.

Performance of interspecific lines (*Oryza glaberrima* × *O. sativa*) under aluminium-toxicity growing conditions

Background information

About two thirds of the West African upland rice is produced in the humid forest zone on highly weathered phosphorus (P)-deficient acidic soils. Aluminum (Al) toxicity is very serious on this type of soil and causes other abiotic stresses, resulting in reduction of rice yields. However, information is limited on Al tolerance in NERICA lines.

The objective of the reported study conducted at the Experimental Station in Nakhon Nayok, Thailand, was to evaluate Al tolerance in several interspecific lines, including the NERICA rice (WARDA, 2006 Joint Interspecific Hybridization Project Progress report 2003–2005, pp. 135–140).

Forty-five interspecific lines, including 33 WAB450-derived and 12 WAB1159-derived lines, and 14 check lines, including 12 sativa and two glaberrima lines, were used. Germinated seeds were placed in a sand nursery bed in a greenhouse and the seedlings were grown for two weeks with Yoshida nutrient solution adjusted to pH 5.3. The nutrient solution was renewed every 2 days. The seedlings were transplanted on a plate of Styrofoam floated in a container (90 x 90 x 50 cm) filled with Yoshida culture solution at pH 3.5, and grown for 14 days after transplanting. The Al concentration in the nutrient solution was changed by adding 0.15, 0.3, 0.6, and 1.2 mM aluminum chloride ($\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$). The plants were harvested 14 days after the initiation of the treatment and served for the determination of the dry weight and Al content in the shoots and roots.

Highlights

Among the 45 interspecific lines, 12 showed better growth in Al-treated conditions than any check lines except IR53650 and CG14 in terms of dry matter weight and hematoxylin staining characteristics (Figure 20; Table 17). From the results of hematoxylin and dry weight determination, the tested interspecific lines were classified into seven groups. The Al-tolerant groups, which are derived from WAB450 (10 lines) and WAB1159 (2 lines), revealed higher dry weight than Al-intolerant groups in such high Al concentrations as 0.6 mM and 1.2 mM (Table 17). The analysis of the distribution of Al in the shoots and roots showed the accumulated Al in the belowground biomass was approximately 10-fold higher than in the aboveground biomass, irrespective of the groups (Figure 20). There was no significant difference between tolerant and intolerant groups in the Al accumulation in the roots. However, in the shoots, a significant difference in Al accumulation was found between tolerant and intolerant groups. When the plants were grown in low Al concentrations (0.15 mM or 0.3 mM), the Al contents in the shoots was higher in glaberrima (2 lines) than in all the other lines. When the plants were grown in high Al concentrations (0.6 mM or 1.2 mM), Al contents in the shoots were lower in the three tolerant groups than in glaberrima and the 3 intolerant groups. The WAB450-derived tolerant group showed the lowest Al accumulation in the shoot, followed by WAB1159-derived tolerant, sativa tolerant, glaberrima, WAB450-derived intolerant, WAB1159-derived intolerant, and sativa intolerant group.

This study identified two lines in the WAB450-derived tolerant group, namely WAB450-I-B-P-69-HB and WAB450-I-B-P-82-1-1, which have extremely strong tolerance against Al treatment (Figure 21), implying that these two interspecific lines can be a useful genetic resource for Al tolerance in rice.

Table 17. Difference in dry matter production of rice groups, including interspecific lines grown for 14 days in various Al-treated solutions

Shoot	Absolute basis					Normalized basis*				
	Dry weight of shoot (mg plant ⁻¹)					(%)				
	Low pH	0.15mM Al	0.3mM Al	0.6mM Al	1.2mM Al	Low pH	0.15mM Al	0.3mM Al	0.6mM Al	1.2mM Al
glaberrima	165±26	118±10	98±16	98±16	93±16	100	71	59	59	56
S.T**	203±7	133±16	118±10	115±12	105±12	100	65	58	57	52
S.Int	115±10	70±7	45±4	43±4	38±4	100	61	39	37	33
WAB450. T	192±8	157±8	138±6	133±6	112±7	100	82	72	69	58
WAB450. Int	137±5	92±3	75±3	65±2	60±2	100	67	55	47	44
WAB1159. T	105±6	105±3	98±7	98±7	88±13	100	100	93	93	83
WAB1159. Int	113±9	84±6	61±6	56±5	47±5	100	75	54	50	42

Root										
	Low pH	0.15mM Al	0.3mM Al	0.6mM Al	1.2mM Al	Low pH	0.15mM Al	0.3mM Al	0.6mM Al	1.2mM Al
glaberrima	43±10	33±4	30±6	30±6	26±5	100	76	71	71	62
S.T	45±3	33±4	30±3	28±4	25±3	100	72	67	61	56
S.Int	34±3	21±2	13±2	11±1	8±1	100	61	39	31	24
WAB450. T	47±2	41±2	39±2	39±1	37±1	100	87	83	82	78
WAB450. Int	40±1	30±2	26±1	21±1	20±1	100	76	66	54	51
WAB1159. T	35±0	35±0	30±3	30±3	23±1	100	100	86	86	64
WAB1159. Int	29±1	23±2	18±1	16±2	12±1	100	79	62	53	41

* Normalized basis = percentage ratio of the Low pH.

**Abbreviation: S.T = sativa-tolerant; S.Int = sativa-intolerant; WAB450.T = WAB450-derived tolerant; WAB450.Int. = WAB450-derived intolerant; WAB1159.T = WAB1159-derived tolerant; WAB1159.Int = WAB1159-derived -intolerant.

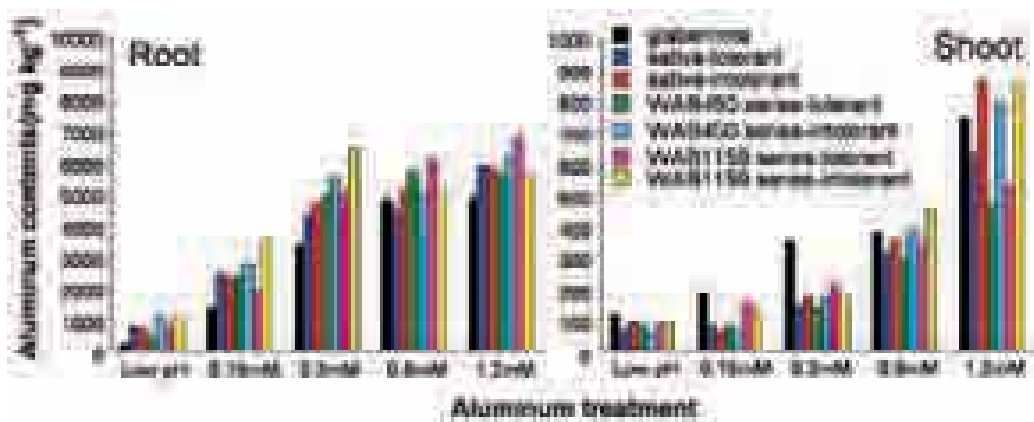


Figure 20. Aluminum accumulation in roots and shoots grown for 14 days in different Al-treated solution conditions (pH 3.5).

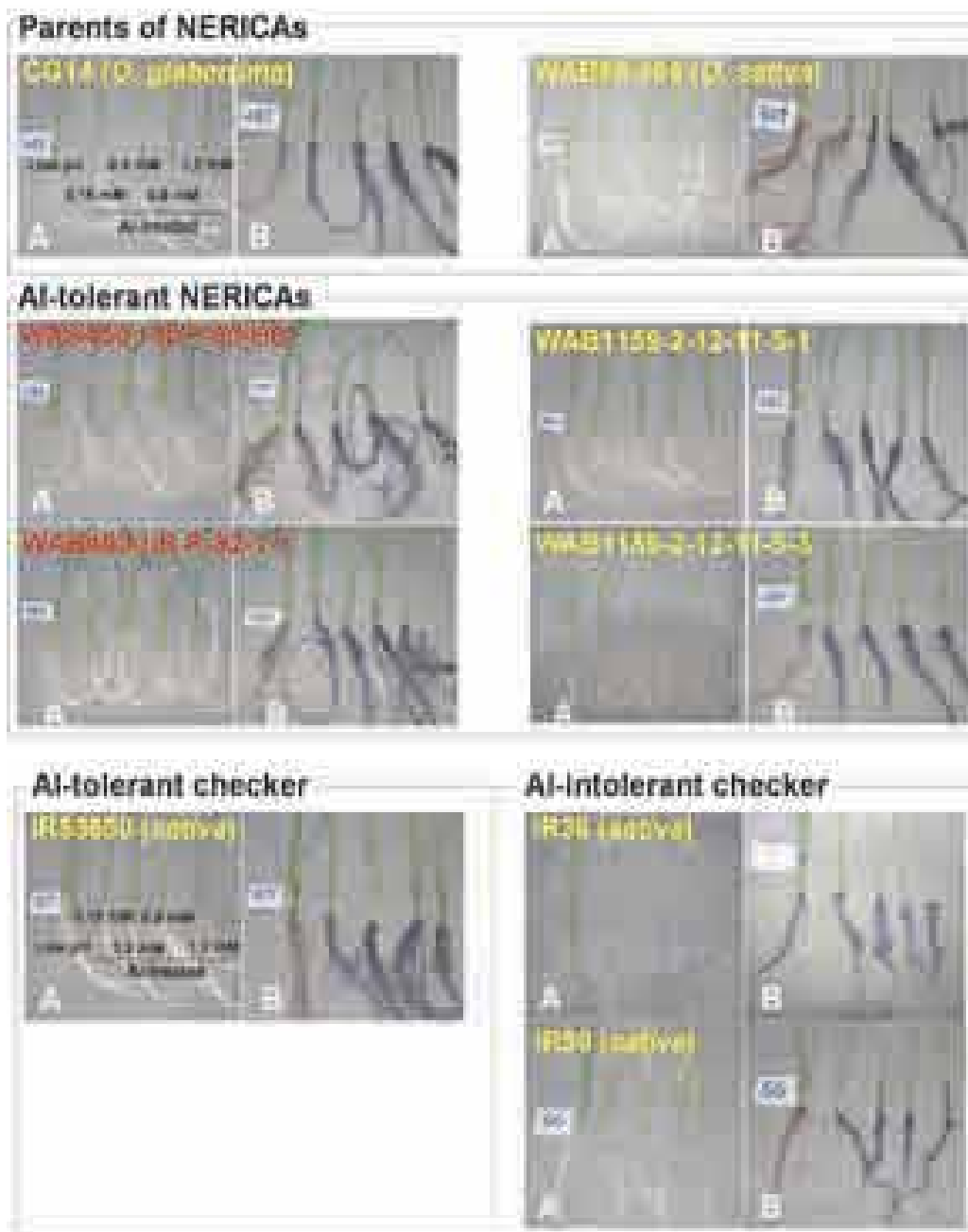


Figure 21. Phenotypic analysis of Al tolerance: Comparisons of root volume and hematoxylin staining in Al-tolerant vs. Al-intolerant rice: (A) Visual symptoms of Al toxicity in the roots; (B) Hematoxylin staining patterns showing differential Al accumulation in the roots.

INTEGRATED PEST MANAGEMENT (IPM) STRATEGIES FOR NERICA VARIETIES

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A Hamadoun*

Unit 1 – Major insect pests of rice

Table 18 summarizes the major insect pests of rice, which cause yield losses from 10–100% in farmers' fields in some West African countries (Nacro *et al.*, 1996;Ukwungwu *et al.*, 1989). Attempts to help rice farmers reduce the damage caused by these pests is a major challenge to agricultural researchers in West Africa.

Table 18. Distribution and host range of economically-important stem borers of rice in West Africa

Common name	Species	Order: Family	Distribution	Host range
Pink stalk borer	<i>Sesamia calamistis</i> Hampson	Lepidoptera: Noctuidae	Cameroon, The Gambia, Ghana, Côte d'Ivoire, Niger, Nigeria	Rice, maize, sorghum, wheat, millet, sugar cane, wild grasses
Pink stalk borer	<i>Sesamia nonagrioides botanephaga</i> Tams & Bowden	Lepidoptera: Noctuidae	Ghana, Côte d'Ivoire, Nigeria	Rice, maize, sorghum, wheat, millet, sugar cane, wild grasses
Pink stalk borer	<i>Sesamia penniseti</i> Tams and Bowden	Lepidoptera: Noctuidae	Ghana, Côte d'Ivoire, Nigeria	Rice, maize, sorghum, wheat, millet, sugar cane, wild grasses

Module 8

Integrated Pest Management (IPM) Strategies for NERICA

Pink stalk borer	<i>Sesamia poephaga</i> Tams and Bowden	Lepidoptera: Noctuidae	Nigeria	Rice, maize, sorghum, wheat, millet, sugar cane, wild grasses
Striped stem borer	<i>Chilo zacconius</i> Bleszynski	Lepidoptera: Crambidae	Benin, Burkina Faso, Cameroon, Cote d'Ivoire, Mali, Niger, Nigeria, Senegal, Sierra Leone	Rice, sorghum, <i>Echinochloa crus-galli</i> , <i>Pennisetum</i> spp.
Yellow stem borer	<i>Scirpophaga melanoclista</i> Meyrick	Lepidoptera: Crambidae	Cameroon, Cote d'Ivoire, Mali, Nigeria, Senegal	Rice
Yellow stem borer	<i>Scirpophaga subumbrosa</i> Meyrick	Lepidoptera: Crambidae	Ghana, Mali	Rice
African white borer	<i>Maliarpha separatella</i> Ragonot	Lepidoptera: Pyralidae	Cote d'Ivoire, Mali, Nigeria	Cultivated and wild rices (<i>Oryza barthii</i> , <i>O. longistaminata</i> , <i>O. punctata</i>)

Stalk-eyed flies	<i>Diopsis longicornis</i> Macqart, <i>Diopsis apicalis</i> Eiman, <i>Diopsis collaris</i> Westwood	Insecta: Diptera: Diopsidae	Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo	Rice, sorghum, millet, <i>Cynodon dactylon</i> , <i>Cyperus difformis</i> , <i>Paspalum orbiculare</i>
African rice gall midge	<i>Orseolia oryzivora</i> Harris & Gagné	Insecta: Cecidomyiidae	Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo, Malawi, Tanzania, Uganda and Zambia	<i>Oryza sativa</i> , <i>O. glaberrima</i> , interspecific progenies, wild species (<i>O. longistaminata</i> , <i>O. barthii</i> , <i>O. punctata</i> , <i>O. stapfii</i>)

Module 8

Integrated Pest Management (IPM) Strategies for NERICA

African white borer	<i>Maliarpha separata</i> Ragonot	Lepidoptera: Pyralidae	Côte d'Ivoire, Mali, Nigeria	Cultivated and wild rices (<i>Oryza barthii</i> , <i>O. longistaminata</i> , <i>O. punctata</i>)
Stalk-eyed flies	<i>Diopsis longicornis</i> Macqart, <i>Diopsis apicalis</i> Edman, <i>Diopsis collaris</i> Westwood	Diptera: Dipsosidae	Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo	Rice, sorghum, millet, <i>Cynodon dactylon</i> , <i>Cyperus difformis</i> , <i>Paspalum orbiculare</i>
African rice gall midge	<i>Orseolia oryzivora</i> Harris & Gagné	Diptera: Cecidomyiidae	Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo, Malawi, Tanzania, Uganda and Zambia	<i>Oryza sativa</i> , <i>O. glaberrima</i> , interspecific progenies, wild species (<i>O. longistaminata</i> , <i>O. barthii</i> , <i>O. punctata</i> , <i>O. stapfii</i>)

Unit 2 – Major Components in Integrated Pest Management (IPM) Strategies

Background information

Integrated pest management (IPM) is particularly relevant to subsistence agriculture. It is environmentally safe, socially acceptable, economically feasible, and compatible with other non-disruptive pest control methods. IPM options include varietal resistance/tolerance, biological control and cultural practices.

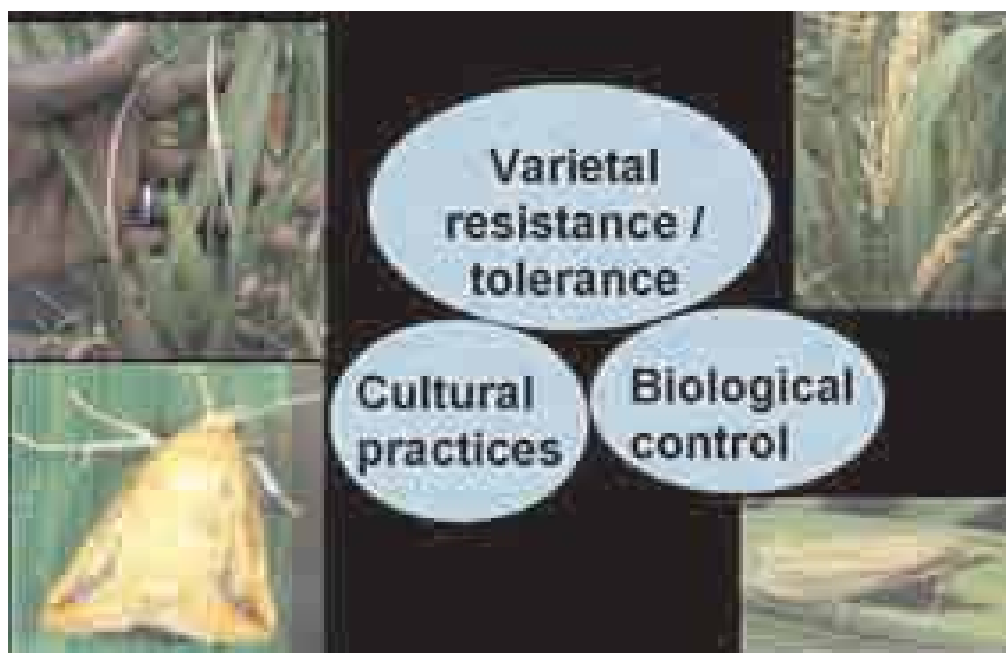


Figure 22. Symptoms of rice stem borer damage and components of IPM strategies

1. Varietal resistance/tolerance

Key Issues: stem borers/termites

- Rice mixed with maize is a common feature of traditional upland rice cultivation

- Can maize be used as a trap crop to protect rice against stem borers?
- Can traditional management practices for termites be integrated with botanicals

Objective	Methodology	Results
To evaluate management components for rice stem borers in rice-based systems	Strip-cropping maize with 19 NERICA varieties in alternate rows, direct seeded, RCB design with 3 replications	There was less stem borer damage on NERICA lines than on maize (Interspecific Hybridization Program IHP Report 2000)
To evaluate management component for termites in rice fields	NERICA1-7, LAC 23, OS 6, Furadan mixed with gari, neem oil, powder, ripe pawpaw mixed with red palm oil;split plot design with 3 replications	Furadan and gari, and neem seed oil, gave the best protection. NERICA5 was the least attacked (Nwilene <i>et al.</i> , working paper, WARDA)

1.1 Stem borers

Background information

Resistant varieties are an important component of integrated pest management. Most of the traditional *Oryza sativa* varieties grown in Africa are low yielding and highly susceptible to stem borers. Are NERICA varieties more or less vulnerable to stem borer damage than their parents or other landraces? What is the level of resistance or tolerance to stem borers among the named NERICA varieties?

Highlights

- To what extent might NERICA varieties be resistant or vulnerable to stem borer damage?

Stem borer pressure may greatly vary across locations and years, attributable to differences in agroclimatic conditions or crop management factors. Thus, NERICA lines have varying levels of resistance to stem borers across locations as summarized below.

Objective	Methodology	Results
To identify upland NERICA varieties with resistance / tolerance to stem borers in West Africa	NERICA1–7, LAC 23, IDSA 6 were direct seeded in a RCB design with 3 replications in Côte d'Ivoire between 2001–2002	NERICA 4 was resistant to stem borers in Côte d'Ivoire (Rodenburg <i>et al.</i> , 2006)
	NERICA1–7, LAC 23, OS 6; direct seeded; RCB design with 3 replications in Nigeria between 2004–2005	NERICA1 and 5 were resistant to stem borers in Nigeria (Rodenburg <i>et al.</i> , 2006)

In Côte d'Ivoire, West Africa, NERICA4 was found to be resistant to rice stem borers

During the 2001 wet season and under natural infestation at Mbé (Bouaké) in the derived savanna and at Boundiali in the Guinea Savanna, the interspecific WAB 450-1-B-P-133-HB was reported to be the least attacked at both locations.

In Boundiali, NERICA2, NERICA4 and NERICA7 showed less stem borer damage than NERICA1 and NERICA6 as well as the widely-grown susceptible variety check (IDSA 6).

At M'bé, however, the same NERICA varieties (NERICA1, NERICA2, NERICA4, NERICA6 and NERICA7) had more stem borer deadhearts than the susceptible check. WAB450-1-B-P-133-HB was rated moderately resistant in Boundiali. At M'bé, however, it was rated moderately susceptible.

In Nigeria, West Africa, NERICA1 and NERICA5 were rated under field conditions as the most tolerant to rice stem borers, with infestation levels of less than 10 percent.

At Ikenne, under field infestation during the 2005 wet season there was no significant difference in deadhearts between NERICA1, NERICA2, NERICA5 and the resistant local variety check (LAC 23) at 60 days after sowing (DAS). At 90 DAS, NERICA5 was significantly different from the other varieties (NERICA1, NERICA2, NERICA3, NERICA4, NERICA6 and NERICA7). NERICA6 was not significantly different from the susceptible check. NERICA1 and NERICA5 had less than 10% tiller infestation (bored stems) and were rated as the most resistant varieties at Ikenne during the 2005 wet season.

Three lepidopterous borers, *Sesamia botanephaga*, *Chilo zacconius* and *Maliarpha separatella*, were the predominant species on the NERICA varieties. The dipterous stalk-eyed borers, *Diopsis longicornis* and *D. apicalis*, occurred in the field when the NERICA rice crop was at the early vegetative stage of growth.

1.2 Termites

NERICA5 was found to be less susceptible to termite damage even when unprotected. NERICA2 and NERICA3 also show a degree of tolerance to termite.

During the course of the experiments *Microtermes* was the predominant termite species in the field, followed by *Ancistrotermes*, and *Odontotermes*.



Figure 23. Symptoms of termite attack on rice

1.3 African rice gall midge (AfRGM)

Background information

The NERICA varieties have been developed for production in upland systems. Nevertheless, in view of their desirable qualities, they have been evaluated for adaptability and resistance to the AfRGM, which is rather a serious pest of rainfed and irrigated lowland rice in SSA.

Damage by AfRGM is different from that of other stem borer species because the larvae attack the growing points of rice tillers at the vegetative stage (seedling to panicle initiation). Infestation of a tiller prevents panicle production and results in the development of a tubular gall also known as ‘onion leaf’ or ‘silver shoot’.

In spite of the hundreds of screenings of *O. sativa* accessions, very little progress has been made in identifying good donor material with stable resistance to AfRGM. Two Asian *O. sativas* – Cisadane (from Indonesia) and BW 348-1 (from Sri Lanka) – have been selected as varieties tolerant to AfRGM at WARDA. The former was released as FARO 51 in Nigeria in 1998 and the latter was released in Burkina Faso. One disadvantage of Cisadane is that it is rather sensitive to iron toxicity. BW 348-1 has good tolerance to AfRGM and iron toxicity under lowland field conditions. A high-yielding *O. sativa* with strong resistance to AfRGM is not yet available. Many varieties resistant to Asian rice gall midge, *Orseolia oryzae* Wood-Mason, are susceptible to AfRGM.

Highlights

In the 2003 and 2004 wet seasons, 10 interspecific lines from WARDA were evaluated for resistance to AfRGM under natural infestation at two hot-spot locations in Nigeria (Ikwo, southeast and Bida, central Nigeria).

At Ikwo, WAB 875-23AB.1 had the lowest mean plant damage when compared with the resistant check variety TOS 14519.

At Bida, WAB 875-23AB.1, WAB 875-19AB.1 and WAB 875-23AB.2 performed the best among the lines tested.

Earlier, a team of researchers from WARDA and NARS from Burkina Faso, Mali, Nigeria and Sierra Leone identified an interspecific progeny, WAB 450-1-B-P181-22-1-HB, with strong resistance to AfRGM (Williams *et al.*, 2001).

The glaberrima parent of the NERICAs (CG 14) and many other accessions of *O. glaberrima*, have been found resistant to AfRGM (Nwilene *et al.*, 2002) but none of the NERICA varieties has been identified as resistant.

Biological control is an important component of IPM for control of the AfRGM.

2. Cultural practices

Which cropping system incorporating NERICA varieties is most sensitive to rice stem borers?

Background information

Rice mixed with maize (*Zea mays* L.) is a common feature of traditional upland rice cultivation in many West African countries. Maize and rice share some common stem borer species. To what extent might NERICA-maize intercropping influence stem borer activity (infestation, crop damage, species composition)? Can the NERICA varieties be intercropped with maize for more efficient management of stem borers under upland conditions? Can maize be used as a trap crop to protect rice against stem borers?

Highlights

- Intercropping has high potential as a cultural method of controlling the major stem borers on rice
- Maize (*Zea mays* L.) can be a suitable trap crop for NERICA1 and NERICA4 stem borers
- There were fewer deadhearts on NERICA4 cropped with maize than on rice or maize monocultures at Mbéand Boundiali in Côte d'Ivoire, West Africa.
- Strip cropping of four rows of maize alternating with an equal number of NERICA rows was found to be effective in reducing stem borer damage on NERICA varieties. NERICA4 had the lowest number of larvae per plant, followed by the interspecific

lines WAB 880-1-38-19-8-P2-HB and WAB 450-1-B-P-105-HB. The added advantages of strip cropping are improved yields and ease of field operations.

During the course of the experiments *Eldana saccharina* was the predominant stem borer on maize (90%), followed by *Maliarpha separatella* (5%), *Sesamia calamistis* (3%), *Chilo zacconius* (1%) and *Busseola fusca* (1%). Stem borers on rice were *Eldana saccharina* (58%), *Maliarpha separatella* (26%), *Sesamia calamistis* (6%), *Chilo zacconius* (5%), *Diopsis longicornis* (4%) and *Busseola fusca* (1%).

3. Biological control of AfGRM

Background information

Two common parasitoid species, including *Platygaster diplosisae* and *Aprostocetus procerae*, are common natural enemies of AfGRM. These parasitoids also attack a related gall midge species, which thrives on *Paspalum scrobiculatum* but does not attack rice.

Highlights

Planting *Paspalum* at the edges of rice fields attracts *Paspalum* gall midge, which harbors parasitoids. These parasitoids then attack the AfGRM. Planting *paspalum* around the edges of rice fields and planting varieties moderately resistant to AfGRM such as BW 348-1 and Cisadane may reduce the damage caused by this pest.

MAJOR RICE DISEASES AND CONTROL

Contributors: Yacouba Séré, Koffi Akator and Amos Onasanya

Background

Three major diseases of key economic importance are common in West and Central Africa and seriously constrain rice production in most rice ecologies. They include the rice yellow mottle virus (RYMV), bacterial leaf blight (BLB) and rice blast.

Of the three diseases cited above, only blast is specific to the rainfed upland ecology for which the NERICA varieties were developed.

Diseases	Rice ecosystems			
	Upland	Lowland	Irrigated	
			Forest & savanna	Sahel
Blast				
RYMV				
BLB				

Blast is rice fungal disease caused by *Pyricularia grisea* (Cke.) Sacc. [Teleomorphe: *Magnaporthe grisea* (Hebert) Barr] and is particularly dangerous in upland rice, but also causes serious damage in rainfed lowland and irrigated systems. Blast is one of the major constraints to intensification.



Neck blast

Node blast

Leaf blast

Figure 24. Symptoms of leaf, neck and node blast on upland rice

Unit 1 – Integrated management of disease

Background information

In the low-input farming systems of SSA where resource-limited farmers can hardly ever afford external inputs, the control of the above diseases is mainly through the use of resistant/tolerant varieties in combination with sound management practices, such as good weed control. One of the principal components of an integrated management system for diseases is varietal resistance though this can be unstable in space and in time depending to the structure of the pathogen population.

This constraint should be taken into consideration either when diffusing material to farmers or when breeders are selecting donor lines.

Objective	Methodology	Results
To identify rice lines with durable resistance to blast in West Africa	67 entries were evaluated for horizontal resistance to blast in Burkina Faso, Nigeria, Mali and Guinea	<ol style="list-style-type: none"> 1. WAB 56-104 2. WAB 56-50 3. NERICA9 4. NERICA18 5. WAB 881-1-10-37-18-25-P3-HB 6. WAB 880-1-38-18-8-P3-HB 7. WAB 881-10-37-18-15-P1-HB 8. WAB 881-10-37-18-24-P1-HB 9. WAB 881-10-37-18-14-P1-HB 10. WAB 880-1-38-20-23-P1-HB 11. WAB 880-1-38-18-20-P1-HB

Varietal resistance/tolerance to blast

Nine interspecifics, including NERICA9 and NERICA18, consistently show resistance to blast at various hotspots across four countries, namely Burkina Faso, Mali, Guinea and Nigeria.

NERICA12, NERICA15 and NERICA16 show resistance to blast in at least three countries, including Nigeria, Mali and Burkina Faso.

The resistance of the above interspecific lines is believed to be as stable and durable as that of WAB 56-50 and WAB 56-104, which are well known for possessing horizontal resistance to the blast pathogen in West Africa.

IMPROVING THE SEED DELIVERY SYSTEM IN SUB-SAHARAN AFRICA

Contributors: Robert G. Guei, Eklou A. Somado and Michael Larinde

Background information

There is wide consensus that seed, especially of improved varieties, is one of the most important elements for increasing agricultural productivity and improved livelihoods. However, in Africa, only one-third of seed comes from seed companies while two-thirds derive from the informal sector. For example, in Western Africa less than 10 percent of total area is sown to certified seed. Farmers do not use improved seed, mainly because very often it is not available to them or they are not aware of the advantages of using improved varieties. Good quality seed is also not accessible to them as there is often a weak linkage between farmers, extension systems, research institutions and market.

Challenges facing the African seed sector

Seed and plant genetic resources hold many challenges for the range of stakeholders involved in the seed sector such as farmers, seed companies and producers, national seed services, research and extension systems and policymakers.

Farmers

Most farmers in Africa are subsistence farmers who, although custodians of local cultivars, often suffer from non-availability of adequate quantity and quality of seeds to sustain the crop diversity suitable for their agro-ecological and socio-economic needs as well as the demands of consumers. Overall, farmers in remote areas are often cut off from any agricultural development initiatives and

injection of new crops and varieties into their seed systems as rural infrastructure conditions in Africa are the major and most common constraint to the development of agriculture in the region. To improve food security, farmers should have on-going access to quality seed in normal and crisis situations. Viable seed supply systems to multiply and disseminate the seed or plant material are critical for the success of food security and livelihood programs in Africa.

Seed companies and producers

There is a crucial lack of sustainable systems for seed production due in part to the dominance of the public sector in seed production with limited private sector participation in seed production. There is often a lack of a clear national policy where the private sector's contribution to the development of the seed system is recognized and enhanced. Emphasis is sometimes put on large-scale seed companies which concentrate more on countries with big commercial farmers in the eastern and southern African regions. Their share of the African seed market as a whole is small and limited to hybrid maize seed and seeds of a few other high-value crops. They do not commercialize cultivars or varieties of other important food security crops such as rice or cassava with very narrow profit margins, as farmers usually save the seed or planting material for the following season's crops. But these cultivars are the germplasm used by most small and poor farmers, the majority of whom are women. These farmers need to access quality seed, the demand for which could be met by small to medium-scale seed enterprises of varying size and capacities.

These are often made up of individual seed growers, farmer groups or associations, and small seed companies with limited equipment, limited capital investment and very weak market strategies. They have little managerial capacity to undertake seed production and supply as a proper business. Basic accounting, marketing, banking and credit management expertise is often lacking. Also, linkage to research – even where possible – for necessary infusion of good

germplasm is limited. Backup support from the national extension services is often weak, necessary market intelligence is usually absent and necessary investment policy support expected from national authorities is minimal or totally lacking. Seed quality control systems are frequently inadequate, there is only a limited market for economic seed trade within individual countries, and regular hindrance of cross-border trade in seed caused by application of phytosanitary, regulatory and varietal release protocols.

To sum up, the lack of adequate participation by the private sector in seed trade and distribution, the lack of organization in the seed market, and the lack of economically-worthwhile seed demand from growers create a serious bottleneck in seed sector development in Africa. The farmer-based seed system still prevails and finding how to link it with a national seed system remains a major impediment to the production of quality seed and to functional distribution channels to ensure access by farmers either within the country or at the regional markets.

Plant breeding/variety improvement

Lack of national capacity in plant breeding has been a chronic limitation to crop improvement in many African countries. This is so partly because investment in plant breeding must be constant and adequate to ensure that trained scientists have resources to run effective breeding nurseries and trial plots in multiple locations for each major crop where improvement is a priority. There are few well-trained scientists and only a handful of these continue with the activity. Such common breaks in continuity of the breeding process generally result in major losses in efficiency. Stronger and regular support to national plant breeding, linked to extension and to farmers to test new varieties, is essential in nearly all countries in Africa. Sustaining plant breeding activities is crucial for the continued support and injection of new technologies into the seed systems.

Extension services

Most extension services are characterized by a lack of information, technical capacity and logistics for timely delivery of advice to farmers. They have inadequate capacity in terms of personnel and are unable to formulate and implement good and sound technology transfer approaches. Reports from 39 countries in Africa show that 77% of these countries have operational extension services; 69% of these countries have reported that extension services are provided by the government; and 31% are provided by development agencies. Many NGOs are deeply involved in agricultural extension, especially in Chad, Ghana, Malawi, Senegal, The Gambia, Guinea and Sierra Leone. The remaining countries either do not have an extension service or the service that exists is ineffective. Lack of or poor extension services are generally due to financial constraints, poor transportation systems, lack of incentives to motivate extension agents, and poor or inappropriate training of extension agents. A common complaint regarding seed is that extension services do not provide seed of varieties that farmers find suitable for local conditions. Extension services remain fundamental to the success of agricultural development, including seed production and distribution locally.

Policymakers

Many African governments have recognized the fundamental importance of sustainable seed production systems in contributing to increased agricultural production. Presently, the seed policies of most of the African governments are created to ensure that farmers are protected from poor quality seed from traders. Country profiles show that only 25% of sub-Saharan African countries have passed a Seed Act stipulating specific seed regulations that must be satisfied. The remaining 75% of countries in sub-Saharan Africa do not have legislation governing the sale and distribution of seeds. However, in most of those countries where a Seed Act has been passed, putting

the various laws and policies into practice has been impeded by inadequate enforcement mechanisms and lack of logistical, financial and human resources.

Questions relating to the balance between the formal and informal sectors, role of the private sector, subsidies, farmers' and plant breeders' rights, seed legislation, biotechnology, and many more pose difficult challenges for which answers must emanate not from the technical domain but from carefully formulated seed policies. Harmonized regional seed rules will facilitate cross-border movement of seed consignments to alleviate periodic seed shortages. In this regard, several initiatives are now underway on the African continent (UEMOA/CILSS/ECOWAS and SADC countries) with support from regional organizations, donors and FAO that further need to be supported by national governments.

In the light of the above, the development of rice in Africa and particularly of NERICA rice is clearly faced with many challenges, including the performance of the seed delivery systems. Seed systems in Africa, where NERICA varieties originated, are very complex and usually not well understood.

It is worth noting that over the 10 years since the introduction of NERICA varieties with the potential to revolutionize rice production, access to sufficient seed remains a major constraint to the activities of smallholder farmers in SSA.

A study in Nigeria funded by the Gatsby Foundation showed that, although farmers who have access to and have adopted NERICA varieties are deriving higher yields and income, those who do not have regular access to seeds have abandoned NERICA lines in favour of low yielding local varieties (Spencer *et al.*, 2006). New approaches are therefore needed but should aim at direct support to farmer organizations and small businesses to strengthen their capacity to manage a seed enterprise. These should take into

account development objectives such as equity, gender, sustainable development and poverty reduction.

A basket of strategies for sustainable seed production and distribution in SSA

A flexible seed system is crucial to respond effectively to the challenges identified. Given the current status of seed production systems in most SSA countries, it is necessary to recognize the informal sector as an important low-cost source of quality seed, and to use it as a vehicle for providing resource-poor farmers with improved seed of modern varieties at affordable prices. The formal sector can continue producing other high value seed along with the informal sector. The creation of small indigenous enterprises, with low-cost structures and close trustworthy relationships with the farming communities they serve, are believed to be better suited to the task.

The proposed approach to the strengthening of the informal seed sector, especially in West Africa where large scale seed enterprises are rather uncommon, consists of:

- Enhanced access of the informal sector to NARS/IARC-bred foundation (and/or breeder seed);
- Effectively-trained and equipped extension services to advise on seed production, processing, treatment and storage.

The Africa Rice Center (WARDA) Experience

The Africa Rice Center (WARDA) has been active in SSA in matters concerning seed and food security. The Center has explored and adapted a range of partnership models that has reinforced SSA's capacity for rice seed production and distribution. These include several participatory models, such as Participatory Varietal Selection (PVS), Community-based Seed Production Systems (CBSS) and Participatory Learning and Action Research (PLAR). Introduced

for the first time in SSA, PVS has revolutionized the scientist-farmer interaction across SSA and unleashed the NERICA adoption wave. The implementation of the project on Participatory Adaptation and Diffusion of technologies for rice-based systems (PADS) used the CBSS-approach to stimulate farmers in taking the lead in seed supply. PVS and CBSS involved more than 20,000 farmers and many tonnes of NERICA seed were produced and distributed across SSA. Local networks and communication channels have been used to promote the new NERICA seed in which NGOs played a crucial role. PADS also developed extension materials such as technical fact sheets and leaflets on improved rice varieties, weeds and fertilizer management, the use of bio-pesticides, improved parboiling technology, etc.

Scientists from NARS partners and farmers' groups have been trained in seed production and varietal release procedures during workshops regularly organized by WARDA since 2000 with hundreds of participants from 30 countries in SSA. In these gatherings, policy reforms required to strengthen the seed sector have been discussed, including intellectual property rights, biotechnology and biosafety regulations.

The Africa Rice Center has also contributed to several initiatives to facilitate the harmonization of regional seed rules with the aim of easing cross-border movement of seed consignments and consequently alleviating seed shortages. As a result of WARDA's active involvement, several initiatives are being undertaken with support from regional organizations (UEMOA/CILSS/ECOWAS in West Africa and SADC in Southern Africa) and multilateral donors that need to be supported by national governments. These governments have realized the need for a basket of strategies to address the complex issue of quality seed production and distribution in their respective countries. Many countries in SSA have become aware that increased food production depends critically upon country-specific and crop-specific seed systems which meet the seed needs of a range of farmers, particularly smallholders.

They have committed to paying increased attention to:

- implementing a legal framework that permits the marketing of uncertified, “truthfully labelled” seed, which would conform to the prescribed standards regarding the genetic purity, germination and moisture content laid down for the variety, except that it would not carry an official certification tag
- the production of breeder seed and, in some cases, foundation seed
- quality control and maintenance of reserve stocks of seed
- implementation of the national seed policy.

Through its partnerships and network activities, as well as its policy research, the Africa Rice Center is encouraging the private and public sectors towards sustainable impact on constraints such as seed availability, support to farmers and small businesses within farming communities, access to inputs, product quality and markets. The aim is to substantially minimize the impact of these constraints with the specific objective to develop and promote public-private partnerships for sustainable seed production and distribution in sub-Saharan Africa.

IMPROVING NERICA SEED AVAILABILITY TO END-USER FARMERS

Contributors: Robert G. Guei, Eklou A. Somado and Inoussa Akintayo

Unit 1 – Conventional Seed Production Scheme vs. Community-based Seed Production System

Background information

The ever-pressing demand to make NERICA seed available to end-user farmers remains a challenge many years after the initial introduction of these varieties in SSA in 1996. Weakness in the assessment and planning of seed needs as well as weakness in SSA's national seed systems are the main constraints to NERICA rice seed availability.

In fact, how long does it take a newly-released improved rice variety to get into the hands of an innovative farmer for cultivation?

Conventional Seed Production Scheme: The conventional seed multiplication system currently in operation in most countries in WCA is typical of most developing countries. Once a variety is released, the breeder provides parental materials (G0) from which three classes of seeds are obtained: 1) breeder seeds (G1, G2 and G3); 2) Foundation Seed (G4); and 3) Certified Seed (R1 and R2). This system requires six years from the release of a variety to produce sufficient seed for distribution to a large number of farmers. Consequently, farmers do not grow the new variety until the seventh year after its release. In general, the seed multiplication and delivery systems of the formal seed industry are inadequate and have concentrated on the production and distribution of high value crops, especially hybrids, which have failed to meet the seed needs of the majority of smallholder farmers. In most countries, little attention has been paid to rice varieties.

In the absence of a formal seed sector in most SSA countries, farmers remain dominant as seed sources.

Community-based Seed Production System: As reported in Module 3, WARDA introduced a new seed multiplication scheme, dubbed the Community-based Seed Production System (CBSS), that uses farmers' practices and indigenous knowledge, and acts as an alternative seed supply mechanism for smallholder farmers. The CBSS strengthens farmers' capacities in the techniques of good quality seed production. The aim of a community-based seed multiplication scheme is to promote on-farm production of quality rice seed through the involvement of individual farmers or farmers' groups in such schemes.

In this system, the national seed service may certify only G2, G3 or G4 (Beye, 2000). The extension services make small quantities of these seeds available to various informal seed growers, e.g. farmers' cooperatives, private seed producers and NGOs. These may produce non-certified basic seed for their regions, from which trained farmers will produce seed of better quality for their communities using their normal production practices. In this way, seed can be provided for many farmers within four years of the release of a variety, three years earlier than in the conventional system. Seed production and distribution are done according to the farmers' practices and capabilities, with some simple guidance given to help farmers maintain the purity of seeds for a period of 3–5 years. Rice is a self-pollinating crop and seed stocks do not need to be replaced every season. However, extension agents monitor germination ability and purity of seed at the farm level.

CBSS has been adopted by many countries in West Africa, but particularly Guinea and Côte d'Ivoire. The experience in these countries has been successfully transferred to several West African countries and is at the heart of the success of NERICA varieties in this region.

Unit 2 – Pathway for NERICA seed production

The African Rice Initiative (ARI), under the aegis of the Africa Rice Center (WARDA), has been put in place to help produce high-quality NERICA seeds, including breeder and foundation seeds, and to facilitate their subsequent dissemination to its national partners in SSA.

Where and how to get high quality NERICA seed?

The national agricultural research systems (NARES) are the privileged partners of ARI for NERICA seed dissemination in SSA. However, NGOs as well as farmers' associations can also be supplied through ARI. Write to the ARI Coordinator for further information (Please visit www.warda.org).

Ideally, rice farmers will be supplied with high-quality seed and advised by their respective NARES as to the relevant NERICA varieties to grow in their locations.

Besides, rice farmers can and should produce and secure their own NERICA seed for planting in their fields.

How to produce high quality NERICA seed?

What is quality NERICA rice seed?

Good NERICA seed should not be infested or damaged

Good NERICA rice seed should not be a mixture (long grain with short grain or fat with thin grain or grain with awns and without awns, black grains with colored grains, etc.).

Variety purity – how to recognize that a rice plant is not a NERICA plant (‘off-type’)?

Based on the NERICA rice variety planted (NERICA1 – NERICA18), and using the characteristics of the passport data of NERICA provided in the Annex to this Compendium, NERICA rice growers should apply the following controls in the field through careful examination of the NERICA rice field:

Check the height (short, tall)

Check the cycle (short, intermediate, long)

Check the leaves (droopy, upright, large, thick, and thin)

Check the grain color (yellow, red, black)

Off-types identified through differences in the above characters can be removed before harvesting and used for consumption.

Harvesting – Threshing – Drying – Storage

Select healthy NERICA plants for harvest;

Carefully harvest each NERICA variety separately;

Avoid mixing other farmers’ varieties with NERICA lines during transportation, threshing and drying and storage;

Before storage, ensure that seeds are properly dried (sun-drying to about 13%) before placing them in bags. Winnow carefully.

Dress the seeds with an appropriate fumigant, e.g. Phostoxin (aluminium phosphide) and dress them with insecticide, e.g. Actellic 50 (pirimiphos-methyl) or as recommended by local agricultural services. Properly label and safely pack bags containing seeds in areas with good air circulation while preparing for the next cropping season.

At the onset of the cropping season, a germination test should be carried out before sowing to ensure good seedling establishment.

Germination testing

Randomly select three sets of 100 seeds of the NERICA rice variety to be sown – Take a shallow basin, which you have previously covered with a wet cloth, or clean jute sacks soaked in water – Place each set of 100 seeds on a cloth then cover them with it – Place the basin in the shade – Slightly moisten as necessary – Avoid the seeds drying out. After 7 days, count the number of seeds that have germinated in each set. If more than 80 of the 100 seeds have germinated, the NERICA seed is good. If less than 80 of the 100 seeds have germinated, the NERICA seed quantity should be increased at planting (i.e. more than 60 kg per hectare).

HARVEST AND POST-HARVEST OPERATIONS

Contributors: Eklou A. Somado and Tareke Berhe

Background information

Harvest and post-harvest operations constitute principal constraints to rice production, especially in irrigated systems, because of the larger yield that has to be handled. Post-harvest crop losses of up to 35% have been reported and attributed to inefficiency of manual threshing of rice by small-scale farmers. This leads to poor grain quality and rejection of locally produced rice. The Africa Rice Center has spearheaded partnership in Senegal between private local companies (SAED) and the Senegalese Institute of Agricultural Research (ISRA) which led to the development of an improved rice thresher cleaner (ASI), in turn leading to a commercial release of the first prototype in 1997 in the Senegal River Valley. The ASI thresher has been widely adopted in Senegal because it enables farmers to produce high value rice with better competitiveness at the market level. The experience in Senegal has been successfully transferred to several West African countries.

The locally-made ASI-thresher can lessen the drudgery associated with hand threshing and improve the usable yield and marketability of rice. Labor is a serious issue in SSA agriculture, and machinery multiplies labor efficiency.

Unit 1 – Harvesting, threshing and cleaning NERICA paddy rice

Harvesting – when to harvest NERICA varieties?

Rice including NERICA varieties is ready for harvesting when the grains are hard and are turning yellow/brown. NERICA rice should be harvested when at least 80% of the upper portion of the main

panicles is straw-colored. The rest of the rice grains should be in the hard dough stage. NERICA varieties should be harvested when grain moisture content is not higher than 20–22%. This should be possible about 4 to 5 weeks after at least 50% flowering of the NERICA rice plants.

Timeliness of harvesting

Proper timing is an important factor in harvesting as it affects field losses and grain quality and then marketability. If harvesting is too early, the volume of immature paddy increases, leading to an increase in broken rice during milling and, consequently, lower head rice yield and quality.

When harvesting is late, the grains are vulnerable to excessive shattering, or can crack during threshing, resulting in grain breakages during milling. In addition, the crop becomes more exposed to attack by rodents, birds and insects; it will also be less resistant to lodging, making harvesting difficult.

How to harvest NERICA rice varieties?

Manual harvesting

Local harvesting methods commonly involve cutting the NERICA stems with a sickle about 10–15 cm above the ground or cutting the panicles. The harvested crop is placed in an upright position for drying before threshing.

Threshing

This operation should be started immediately after harvesting to avoid the harvested stalks turning yellow and associated discoloring.

Mechanical threshing in West Africa is on the increase thanks to the ASI-Thresher developed by WARDA and its partners. ASI is the most widely-used rice thresher in the Senegal River Valley. It is a highly successful product of the partnership-owned R4D system, which is lessening the load of drudgery previously associated with threshing and improving the usable yield and marketability of rice. The success of the low-cost threshers can be seen as the beginning of the path to commercialization for smallholders. Labor is the number one issue in SSA agriculture, and machinery multiplies labor efficiency.

How to thresh NERICA varieties?

Manual

The most frequent threshing method in West Africa is to beat the harvested stalks on a drum or with a stick. However, threshing is best done on a clean tarpaulin and never on the bare ground. This avoids stones mixing with rice, which reduces the quality and the subsequent marketability of the NERICA rice.



Figure 25. Mechanical threshing of NERICA varieties

Cleaning of grain

Clean threshed grain to remove impurities such as bulky straws, chaff, weed seeds, leaves, pods, sticks, stones and other foreign matter. Clean grain has improved storability, better milling output and quality resulting in a higher marketable value.

Winnowing

Winnowing helps remove light and chaffy material and can be done manually without delay after threshing to avoid contamination and poor quality black rice. Modern rice mills reduce the burden of winnowing mainly carried out by farmers.

Unit 2 – Drying, storing and milling NERICA varieties

Grain drying

Because of their short cycle the NERICA varieties may be ready for harvest during the rainy season with consequent difficulties of sun drying.

Given that the paddy NERICA rice is harvested in the field at a moisture level of 20–22%, attempting to store it in this condition will cause grain quality deterioration. To maintain seed quality during storage, paddy rice should therefore be dried to a moisture content of 13–14% (wet basis).

When and how should NERICA varieties be dried?

Drying of grain should immediately follow threshing. Drying should be on concrete floors or mats and should be carried out gradually for the first few days to reduce breakage during milling. To reduce the introduction of sand pebbles and other foreign matter into the paddy, it is important to avoid drying on bare floors.

Sun drying is the traditional method used by most farmers in West Africa, because it is freely available and may give better than or

comparable results to conventional but costly methods (Somado *et al.*, 2006). However, the viability of the grain as seed can be adversely affected by untimely sun drying. Rice grain can be sun-dried 4 to 6 hours a day for 5–7 days by spreading grain in thin layers on the tarpaulin or clean floor. It is recommended to turn and stir the grain many times a day (5–6 times) for even moisture distribution and rapid drying. When the grain is suitably dried for quality storage (13–14% moisture content), it breaks easily into two when bitten between teeth. However, the use of a moisture meter can indicate the moisture level of the dried grain more accurately.

Storage

To ensure long and safe storage of NERICA paddy rice a few precautions are needed. NERICA is no exception. The paddy rice must not contain more than 13–14% moisture, and be handled in a way to avoid moisture absorption either from rainfall or the moist air. Paddy should be protected from insects and rodents.

Milling

The most critical factors that control optimum milling recovery (ratio of milled rice output to paddy input) include:

- moisture content: no more than 13–14%
- purity: the presence of impurities reduces the milling recovery and quality
- cracked grain: this breaks easily during milling and whitening, thus reducing milling quality
- varietal characteristics: varieties differ in their milling abilities.
immature grain – the husk content of immature grain can be as high as 40%

Milling equipment – the use of mortar and pestle (hand pounding) is still common in West Africa even if more modern equipment is progressively being used.

GRAIN AND NUTRITIONAL QUALITY OF NERICA VARIETIES

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Background information

Grain quality, including taste, is one of the key selection criteria highly prioritized by farmers and consumers of the NERICA varieties as highlighted in the farmers' participatory varietal selection (PVS) trials across West Africa. Desirable NERICA varieties should have not only excellent agronomic performance but also grain quality acceptable to both farmers and consumers.

The pink color of milled rice of *O. glaberrima* (a parent of the NERICA varieties) as a result of its red pericarp is usually not appreciated at the market level. Frequent grain breakage is also an unfavorable trait of *O. glaberrima*. Therefore, for the NERICA varieties to have a high marketable value, these improved varieties should not inherit the unfavorable grain quality of *O. glaberrima*.

Unit 1 – NERICA grain quality characteristics

Background

NERICA is mainly consumed as milled rice in WCA. Milling characteristics of the NERICA varieties determine their grain quality.

In this manual, milling characteristics include i) the husking yield (i.e. the percentage ratio of brown rice/paddy on a weight basis), ii) the milling yield (the percentage ratio of milled rice/ brown rice on a weight basis), and iii) the head rice ratio (the percentage ratio of head rice/milled rice on a weight basis).

High husking and milling yields are indicative of small yield losses. A high head rice ratio corresponds to less grain breakage in milled rice, and this is a desirable trait at market, especially in urban areas. NERICA lines have showed better milling characteristics than *O. glaberrima* for all these parameters.

Many of the NERICA varieties have shown a similar level of good milling characteristics to a leading high-quality improved variety such as Bouaké 189, a popular improved rice variety in Côte d'Ivoire (Watanabe *et al.*, 2002b).

Highlights

The dimensions of a milled grain of a NERICA variety vary in the range of length (L), 5.6–7.7 mm; width (W), 2.3–3.3 mm; thickness (T), 1.7–2.1 mm; L/W ratio, 2.1–3.0. Rice with slender grains (grains with high L/W values) is generally preferred in WCA.

The average L/W ratio in NERICA varieties is 2.6, which is similar to the 2.7 measured in Bouaké 189, but lower than the L/W ratio of 4.0 measured in IDSA 85, another promising variety in Côte d'Ivoire (Watanabe *et al.*, 2002a and 2002b).

Aromatic rice is highly preferred in WCA. Several aromatic lines were identified among NERICA crosses. One example is NERICA1.

Amylose content has a strong influence on rice texture which is the most dominant factor to affect rice taste. Higher amylose content corresponds to harder texture in general. Amylose content of WAB56-104, the *O. sativa* parent, and CG 14, the *O. glaberrima* parent, is 21.7% and 26.0%, respectively. NERICA lines show a wide range of amylose content from 15.4% to 28.5%, with an average of 25.0%. Rice consumption preferences differ from one country to another. For example, consumers in Nigeria seem to prefer varieties about 25% amylose content while in Côte d'Ivoire the preferred value varies between 20 and 25%.

Viscosity of rice at high (during cooking) and low temperatures (after cooling) also affect rice texture. The NERICA varieties have quite large variation for this trait.

Unit 2 – NERICA nutritional quality: protein and amino acid content

Background

Rice is already an important staple food crop for millions of households or is rapidly becoming so in SSA. Increasing rice production and improving its nutritional quality is expected to make a tremendous contribution to improving the livelihoods of millions of households.

Both the high yield of NERICA varieties and their good nutritional quality are expected to play a significant positive role towards the elimination of hunger and malnutrition in sub-Saharan Africa.

Highlights

- NERICA varieties' consistent nutritional quality over years and across countries in West Africa.
- Parboiling has no effect on NERICA amino acid values.
- NERICA2 and NERICA7 (milled) have the highest protein contents (11.8%).
- NERICA4 (milled) has the lowest protein content (9%) – still greater than in imported rice.
- NERICA1 to NERICA6 (milled) have higher protein (9–11%) than imported (7.7%) and USDA standard rice (8.1%). This represents 26–32% higher protein.
- NERICA rice prepared by the parboiling method has higher average protein (10.7%) and amino acid balance than directly milled NERICA rice (10.2%).

- The milled NERICA varieties have higher protein contents and show a better balance of amino acids as compared to both imported varieties and the international rice standard.
- The high protein content and good balance of essential amino acids in NERICA varieties can play a significant role in combating malnutrition in many sub-Saharan African countries where rice is the main staple food.
- One could calculate the Africa-wide benefits of this extra protein from many angles: health, substitution for costlier protein sources, mental development in youths, etc.
- High micronutrient (iron and zinc) concentration in some interspecifics (Table 19).

Table 19. Rice varieties combining both high Fe and Zn concentration (mg.kg^{-1}) in brown rice samples

Ecology	Rice variety	Iron	Zinc
Upland	WAB 891-SG-25	21.1	53.2
	WAB 709-73-3-2	23.1	57.3
	WAB 488-161-2	25.3	48.7
Lowland	WAS 63-22-1-1-3-3	18.5	38.9
	WAS 127-B-5-1	15.8	42.9

Table 20. Protein and selected amino acid values (%) of NERICA rice from Guinea, analyzed* in 2003, and from Benin analyzed in 2005

Variety	Seed component	Polished 2003	Polished 2005	Parboiled 2003	Parboiled 2005
NERICA1	Protein	10.68	10.04	10.70	11.02
	Lysine	0.35	0.40	0.40	0.42
	Tryptophan	0.08	0.13	0.10	0.13
	Methionine	0.36	0.31	0.33	0.33
NERICA2	Protein	13.25	10.48	13.64	11.81
	Lysine	0.34	0.39	0.35	0.44
	Tryptophan	0.08	0.11	0.11	0.13
	Methionine	0.38	0.27	0.41	0.37
NERICA3	Protein	9.95	10.20	10.1	11.14
	Lysine	0.35	0.39	0.40	0.40
	Tryptophan	0.09	0.11	0.10	0.09
	Methionine	0.34	0.27	0.36	0.28
NERICA4	Protein	8.33	8.87	9.41	9.51
	Lysine	0.26	0.36	0.31	0.35
	Tryptophan	0.06	0.10	0.10	0.12
	Methionine	0.29	0.23	0.34	0.17
NERICA6	Protein	8.7	10.34	9.6	10.76
	Lysine	0.33	0.43	0.36	0.43
	Tryptophan	0.09	0.14	0.10	0.13
	Methionine	0.32	0.37	0.44	0.37
NERICA7	Protein	-----	10.43	-----	11.69
	Lysine	-----	0.40	-----	0.43
	Tryptophan	-----	0.12	-----	0.12
	Methionine	-----	0.34	-----	0.37
Taiwanese	Protein	7.58		-----	
	Lysine	0.34		-----	
	Tryptophan	0.08		-----	
	Methionine	0.38		-----	
Chinese	Protein	7.94	9.49**	-----	10.14**
	Lysine	0.33	0.37	-----	0.37
	Tryptophan	0.07	0.11	-----	0.10
	Methionine	0.37	0.31	-----	0.31

* Analysis of NERICA9-NERICA18 is being done and result will be reversed to an updated version of this Compendium

** Values are for NERICA8

NERICA IMPACT AND ADOPTION IN SUB-SAHARAN AFRICA

Contributor: Aliou Diagne

Background information

Since 1996 rice farmers in many countries in West, Central, East and Southern Africa have been exposed to NERICA varieties. Have they made any difference in the lives of these farmers?

The Africa Rice Center (WARDA), in collaboration with its NARS partners, initiated studies on the impact of NERICA rice adoption in nine countries of West Africa, comprising Benin, Côte d'Ivoire, The Gambia, Ghana, Guinea, Mali, Nigeria, Sierra Leone and Togo. By 2006 the studies were completed in Benin, Côte d'Ivoire and Guinea.

Below are summarized the major findings from the aforementioned studies are summarized below.

Unit 1 – NERICA diffusion and adoption

In Côte d'Ivoire, a low diffusion rate (9%) limited the adoption of the NERICA varieties to only 4% in the year 2000. But the adoption rate in the population could have been up to 27% had the whole population been exposed to the NERICA technology (Diagne, 2006a).

The rate of NERICA diffusion was 39% in Guinea, a diffusion rate much higher than that in Côte d'Ivoire. The NERICA population potential adoption rate (were all the farmers in Guinea exposed to the NERICA) is 58%, double the actual adoption rate of 23% observed in the sample (Diagne *et al.*, 2006a). Up to 53% of farmers who were exposed to NERICA lines had adopted them in 2001. The total area under NERICA varieties in Guinea has been estimated to be 28,000

hectares in 2002 and 51,000 hectares in 2003 (Diagne *et al.*, 2006b). The total area planted to NERICA varieties is growing fast and has quickly surpassed that covered by the modern varieties of the Institut de Recherches Agricoles de Guinée – IRAG. The total estimated area in 2006 was, however, but a third of the potential area had all farmers known about NERICA varieties and had access to seed.

In Benin, the NERICA diffusion rate in 2004 was 26%. NERICA varieties were adopted by 18% of the sample of 304 rice farmers surveyed in 24 villages in 2004; this adoption rate was three times lower than estimated potential adoption rate of 57%. Up to 68% of farmers who were exposed to NERICA varieties in Benin in 2004 adopted them. About 2000 hectares were estimated to be under NERICA lines in Benin in 2003. The potential area under NERICA varieties in 2003 (had all farmers known about the NERICA breakthrough) was estimated to be 5500 hectares (Adegbola *et al.*, 2006).

Unit 2 – Determinants of NERICA adoption

The results of the econometric analysis of the socioeconomic determinants of NERICA adoption in Côte d'Ivoire show that the main factors which affected the adoption of NERICA varieties (i.e. with estimated effects statistically significant at the 5% level) were growing rice partially for sale (positive impact), household size (positive), age (negative impact), having a secondary occupation (negative impact), growing upland rice (positive impact), and past participation in PVS trials (positive impact) and living in a PVS-hosting village (positive impact) (Diagne, 2006b). In Guinea, the main socioeconomic determinants of NERICA adoption with positive effects were participation in a training program and living in a village where the NGO SG2000 has previously had activities (Diagne *et al.*, 2006b). In Benin, the main socio-economic determinants with positive effects were land availability and living in a PVS-hosting village. In addition to the analysis of the socioeconomic determinants

of NERICA adoption, it was also found in Benin that varietal attributes such as swelling capacity and short growing cycle were important determinants of NERICA adoption (Adegbola *et al.*, 2006).

The policy implication of the empirical findings regarding the important role played by PVS both in the diffusion and adoption of the NERICAs and both within and outside the populations involved in the trials goes beyond the endorsement and promotion of PVS as an effective tool for technology development and dissemination. Indeed, the finding that the mere conduct of PVS trials in a community promotes the adoption of NERICA varieties beyond the subpopulation participating in the trials points to a possible strategy for scaling up PVS: focus on covering more villages with relatively few PVS participants per village (i.e. inter-village scaling up) and let the naturally-occurring phenomenon of “social learning” about the characteristics of a technology do its work within the village community (i.e. the intra-village scaling up).

Unit 3 – Impact of NERICA adoption

In Côte d’Ivoire, the NERICA impact assessment results show the impact of NERICA adoption on the average yield of rice to be heterogeneous, with a sizable and statistically significant impact found for female farmers (+741 kg/ha) and no statistically significant impact found for male farmers (Diagne 2006b). The results also suggest that a large number of farmers, especially those in the forest ecology, adopt the NERICA not because of its yield potential but because of its non-yield varietal attributes such as its short growth cycle, height, and consumption and grain qualities.

In Guinea, the results of the analysis of the impact of the introduction of NERICA technology on rice biodiversity shows that the relatively high level of NERICA adoption has not led to a concomitant reduction in the number of pre-existing cultivated rice varieties (Barry *et al.*, 2006). It appears that because of their short duration, the NERICA

varieties are used by farmers as a complement to traditional varieties and thus enhance the varietal diversity of rice.

In Benin, the results of the analysis of data for the 2003 season show that the impact of adoption of NERICA varieties is significant and positive for the yield, production and incomes of producers. Indeed, an additional rice yield gain of 1587 kg per hectare was achieved by NERICA-adopting farmers, giving them a *per capita* rice production gain of 109 kg and additional income of 14 100 FCFA (\approx USD 28) respectively. However, the impact at the national level was very limited because of the present limited diffusion of the NERICA varieties in Benin (Adegbola *et al.*, 2006). Results from another analysis based on data from the 2004 season show that the impacts of NERICA adoption are higher for women than for men. Women potential adopters have a surplus of production of 850 kg of paddy per hectare compared to 517 kg per paddy for men, and an additional gain of 171 978 FCFA (\approx USD 337) per hectare compared to 141 568 FCFA (\approx USD 277) for men (Agboh-Noameshie *et al.*, 2006). Yet another study on the impact of NERICA technology on child schooling in Benin found NERICA adoption to result in a 6% increase in school attendance rate, a 14% increase in the gender parity index and a 11 400 FCFA (\approx USD 20) increase in school expenditure per child (Adekambi *et al.*, 2006).

The impact of adoption of NERICA rice on consumption spending, calorie intake and poverty was also assessed by Adekambi *et al.*, (2006). This study found that NERICA adoption had a positive impact on household spending per equivalent adult (+147.51 FCFA/day \approx USD 0.30). The highest impact was observed in female-headed households (161.75 FCFA/day \approx USD 0.32 compared to 128.34 FCFA/day \approx USD 0.26 for male-headed households). However, the difference between the two groups is not statistically significant.

In addition, the spending deficit ratio of the poor has been reduced by 19%, proving that NERICA adoption has led to an improvement in

the living conditions of poor households, reducing the gap between their expenditure and the poverty line by 19%. The NERICA varieties also led to an improvement in daily calorie intake of 35.82 kcal per equivalent adult (significant at the 10% level).

In the East African country of Uganda, rice was little grown until recently. The country became an early adopter of NERICA technology, and today rice is a cash crop for Ugandan growers. A NERICA-promoting program has been undertaken as one of the major poverty eradication measures. An empirical analysis of NERICA impact on the income of rural households in the country attempted to compare actual crop income with the hypothetical income without NERICA varieties. This study revealed that on average a shift from maize to NERICA varieties with proper crop rotation increased income by between USD 273 and USD 481 per hectare. The introduction of NERICA rice varieties in Uganda tends to improve the incomes of rural households in the country and is seen as a significant entry point for poverty reduction (Lodin, 2005; Kijima *et al.*, 2006).

Table 21. Summary results of the adoption and impact studies in Benin, Côte d'Ivoire, and Guinea.

Category	Benin	Côte d'Ivoire	Guinea
Average adoption rate of NERICA by farmers in sample (year)	18% (2004)	4% (2000)	23% (2001)
Average adoption rate, had all farmers been exposed to NERICA (year)	50% (2004)	27% (2000)	58%
Percentage of farmers adopting after being exposed to NERICA varieties (year)	68% (2004)	38% (2000)	53% (2001)
NERICA diffusion rate – % exposed to NERICA rice (year)	26% (2004)	9% (2000)	39% (2001)

Module 14

NERICA impact and adoption in sub-Saharan Africa

Estimated area under NERICA rice (year)	1995 ha (2003)	-	51,000 ha (2003)
Average NERICA impact on rice yield (year)	1,587 kg/ha (2003)	276* kg/ha (2000)	.085* kg/ha (2003)
Average NERICA impact on <i>per capita</i> rice production per year	109 kg/capita (2003)		
Average NERICA impact on <i>per capita</i> rice income per year	14,100 CFA (≈\$28) (2003)		
Average NERICA impact on yield for female farmers (year)	850 kg/ha (2004)	741 kg/ha (2000)	
Average NERICA impact on yield for male farmers (year)	517 kg/ha (2004)	-134* g/ha (2000)	
Average NERICA impact on income for female farmers (year)	171,978CFA/ha (≈\$337/ha)	-	-
Average NERICA impact on income for male farmers (year)	141,568CFA/ha (≈\$277/ha)		
Average NERICA impact on child school attendance rate	6% (2004)		
Average NERICA impact on the child school gender parity index	14% (2004)		
Average NERICA impact on school expenditure per child	11,400 CFA (≈ \$20) (2004)		
Average NERICA impact on total daily consumption expenditure per adult equivalent	148 CFA (≈ \$0.30) (2004)		
Impact on daily calories intake per adult equivalent	36 kilocalories (2004)		
Impact on the consumption expenditure deficit ratio (compared to the poverty line)	-19% (2004)		

* Not statistically different from zero at the 5% level

POLICIES AND INSTITUTIONS FOR PROMOTING NERICA RICE COMPETITIVENESS IN SUB-SAHARAN AFRICA

Contributor: Patrick Kormawa

Background

WARDA member countries together account for nearly 17% of total world rice imports, amounting to an annual USD 1.4 billion in scarce foreign exchange that could instead be used to import strategic industrial and capital goods.

Rice – a major staple in Africa

The trend in *per capita* rice consumption in West Africa is steadily upwards. It increased from 14 kg in the 1970s to 22 kg per person per year in the 1980s and is in 2005 almost 32 kg per person per year. However, the magnitude of increase during each period is also related to supply. As supply has increased over the years, so has *per capita* consumption which is expected to continue increasing as more rice becomes available and as population increases. This provides governments with both an opportunity and a challenge.

The growing demand provides an opportunity as developments along the rice commodity chain can provide jobs to a significant number of people both in rural and urban areas.

Share of total rice imports in Africa

The leading African rice-importing countries are Nigeria (16%), South Africa (11%), Senegal (9%), Côte d'Ivoire (8%), Sierra Leone (4%), Ghana (4%) and Burkina Faso (3%).

It is projected that imports to these countries will continue to increase in the short and medium term. Among West African countries, the bulk of the projected increase in rice imports and consumption is expected from Nigeria, Senegal, Côte d'Ivoire, Sierra Leone, Mali, Ghana and Liberia, although they all have sufficient suitable agro-ecologies for increasing their domestic rice production. These countries and other West African countries will continue to rely on imports unless new policies and programs to adequately promote domestic rice production and development of regional markets are put in place.

African countries need to wake up and invest in rice production, otherwise they will remain heavily dependent on Asia and the USA to supply rice to feed their growing populations, despite having suitable ecologies and water bodies to support for rice production.

What can policy do to improve the competitiveness of domestic rice?

For rice production in SSA to be competitive, production costs have to reduce, quality has to improve and prices of outputs have to be right. But how can this be done?

1. Develop rural input markets

Unless farmers get access to seeds, chemical fertilizers and other complementary inputs to improve their yields, African rice farmers cannot produce sufficient rice to feed the teeming population.

Governments should be encouraged to establish national Input Credit Guarantee Funds (ICGF) to accelerate the access of farmers to agricultural inputs. The private sector in most of West and Central Africa is not yet developed to the extent it can meet the task of providing sufficient quantities of inputs at the right time. The few private sector input dealers face high risks in supplying rural markets. For example, there is no guarantee that farmers will repay loans if there is a crop failure – a scenario that is mostly due to natural

factors beyond the control of farmers. Governments can set up or be encouraged to use National Input Credit Guarantee Funds to help cover the risk faced by farmers and private input suppliers.

As extension services in most countries are being rationalized, capacity of the agro-input dealers should be enhanced to provide extension messages to rice farmers, particularly about new technologies.

2. Organize the domestic rice market

Following rice market liberalization, farmers themselves now have to find markets for their produce. Lacking collective action, they are unable to negotiate higher prices for their produce with traders.

There is power in organization. When farmers are organized, they can overcome the disadvantage of their atomistic sizes and achieve economies of scale in product bulking, storage, transport and marketing. Most rice farmers do not have access to an organized market for their harvest. They are often left to the mercy of exploitative traders.

As more than 90% of rice farmers in West Africa are smallholders, without an organized market, such farmers will not benefit from economies of scale and size. Thus, policymakers must be encouraged to support programs that organize the rice market so that farmers and rice millers can get better returns on their investments.

3. Set up effective Market Information Services

Market information is needed for farmers to know what to sell – whether paddy or milled rice, where to sell, when to sell, and at what terms to sell to other market participants. The lack of market information creates unequal playing fields between market middlemen and farmers. This negatively affects the terms of trade for smallholder farmers and raises market transaction costs. It also leads to poor integration of markets across space and time.

Because traders do not have access to reliable market information, it is common to find situations of artificial scarcity as surplus areas co-exist with areas of deficits. This has the effect of lowering farm gate prices in surplus areas and raising the price of rice in deficit areas.

4. Improve policy and rural infrastructure

The general policy and rural infrastructure environment needs to be improved to help farmers become competitive in accessing markets and raising their incomes. For this to happen, they need the following:

Credit guarantee facility

Private companies need to be linked up with rural agro dealers; to be part of an innovative private-public-community partnerships

Rice processing technology and quality

Rice processing is constrained by inadequate and inappropriate processing equipment, especially for post-harvest operations at the farm or village level, such as threshing, parboiling, milling, destoning and polishing. The inability to provide and use improved technologies in rice processing has led to the production of poor quality and substandard domestic rice that is not competitively marketable. The unavailability of these accessories and farmer and processor practices account for the poor quality of domestic rice processing.

In some countries, there are few existing large mills and most of these are owned by government or quasi-government parastatals. For example in Nigeria, the Pateggi, Uzo-Uwani, and the Agbede rice mills are typical examples of large mills. These mills combine rice milling with rice polishing, and in most cases they possess separate parboiling equipment. In other major rice producing countries like Sierra Leone, large mills are not popular with the farmers. It is also important to note that the existing large mills have broken down as a result of poor management, under utilization of capacity (leading

to unprofitable businesses), lack of spare parts and the general poor maintenance. Although there are private sector investors that might normally otherwise be willing to acquire and manage such large-scale rice mills, their concerns about policy inconsistency and infrastructure deficiencies are overriding factors for non-acquisition.

The major opportunities in the rice commodity chain lie post-harvest in private and public sector intervention to improve processing standards, quality and grades of domestic rice through investment in rice mills and capacity building for farmers and rice millers. Improved post-harvest technologies to help in the production of uniform rice for seeds or consumption, in drying, destoning and parboiling are necessary. Capacity building will also be enhanced by strengthening processor groups and facilitating linkages not only to improved post-harvest technologies but also to credit. The rice milling industry has considerable potential to increase rural employment but requires initial investment in organization, management and capacity building of the major players in the rice value chain.

Bold government policies needed to help local rice producers

Import tariffs: With the exception of Nigeria, the import tax regime of about 30% for rice in West African Economic and Monetary Union (UEMOA) countries and non-UEMOA countries encourages rice imports against the use of local production.

The Nigerian government's bold step towards improving the competitiveness of domestic rice production in Nigeria is a good example of what can be done. In Nigeria, the tariff on imported rice is about 120%. This policy provides an opportunity for rice farmers as well as millers to invest. The effect is already evident from a declining volume of imported rice with an attendant increase in the domestic price of rice. The volume of rice imported in 2003 was 2.5 million tonnes at the price of NGN 29.85 billion. In 2004 the volume imported was less than 1 million tonnes (0.84 million tonnes) but the price was higher (NGN 30.31 billion). This policy

is also encouraging rice millers to invest in new equipment and to set up growers' schemes with farmers. These initiatives will boost domestic output.

Support science and capacity building

Africa will need to have solid science if it is to address most of the problems facing its farmers such as drought, soil fertility depletion, diseases and pests. The comparatively new science of biotechnology has much to offer. However, human capacity is still limited in this area.

Take advantage of regional initiatives

Sub-Saharan Africa regions should take advantage of the opportunities offered by the subregional organizations – ECOWAS and UEMOA (in West Africa), SADDC (in Southern Africa) – as well as the continent-wide initiative NEPAD to promote rice production. NEPAD has placed emphasis on agricultural development through its Comprehensive Africa Agricultural Development Programme (CAADP), which has a goal of lifting the agricultural growth rate by 6%. CAADP has identified two priority areas that are of importance to rice sector development:

- Harmonizing regional policies (ECOWAAP)
- Scaling up transfer of selected technologies

West African countries should use a subregional approach to promote rice production through common policies and scaling up of rice technologies, within the CAADP framework.

Conclusions

First, there is a need to invest in setting up rural input markets to supply agricultural inputs such as seeds and chemical fertilizers to farmers. Unless farmers get access to seeds, chemical fertilizers and other complementary inputs to improve their yields, West African rice farmers cannot produce sufficient rice to feed the population.

Secondly, post-harvest handling and rice milling has to be improved to ensure improved quality.

Thirdly, the market for domestic rice needs to be organized and improved so they can get better returns for rice produced in Africa.

Fourthly, the general policy and rural infrastructure environment needs to be improved, to help farmers become competitive in accessing markets and raising their incomes.

However, developing competitiveness will need to have solid science if it is to address some of the emerging problems facing farmers such as drought, soil fertility depletion, diseases and pests. Thus support to rice research institutes or programs cannot be overstated. Making markets work for rice farmers must be seen as part of a long-term agenda, for which the development of human capacity is critical.

Knowledge drives product innovation. It provides the ‘searchlight’ and capacity for the identification of new market opportunities. It enhances the ability to compete effectively in markets. Also, knowledge is critical for the development of rice-sector-specific policies, as well as sound market institutions. Rice market ‘knowledge chains’ need to be developed at several levels:

- at the level of farmers associations and civil society
- researchers and policy analysts
- at the level of the private and public sectors.

Module 15

*Policies and institutions for promoting
NERICA competitiveness in sub-Saharan
Africa*

Africa Rice Center (WARDA), a knowledge-driven research and development organization, has dedicated its programs to help farmers, processors, governments, etc. develop country-specific and regional rice development programs to make markets work for farmers.

NERICA AND THE UNITED NATIONS MILLENNIUM DEVELOPMENT GOALS

Background information

The development of NERICA through the partnership-owned Research for Development system has helped WARDA in addressing the United Nations Millennium Development Goal (MDG) priorities. Here are a few illustrations.

MDG1 – Eradicate extreme poverty and hunger

NERICA whose large-scale diffusion was driven by enthusiastic farmer participation has already demonstrated significant impacts on poverty alleviation. In Benin, for example, increased yields as a result of NERICA adoption have increased women farmers' income by USD 337 per hectare of NERICA cultivated (Agboh-Noameshie *et al.*, 2007).

MDG2 – Achieve universal primary education

In 2003–2004 a survey conducted by WARDA in Benin (Module 14) in partnership with the national research program (INRAB) showed that in farming families adopting NERICA there was:

- a 6% increase in children's school attendance rate
- a 3% increase in youngsters continuing primary education
- about USD 20 increase per child in school expenditure.

A study of NERICA rice growers in Uganda also highlighted schooling as a priority (Kijima *et al.*, 2006a and 2006b).

MDG3 – Promote gender equality and empower women

The majority of upland rice farmers in SSA are women, who supply 52% labor in land preparation, 80% in sowing, 88% in weeding and 80% in harvesting. The short duration of the NERICA varieties are one of their major attractions for farmers. This can be a useful trait to escape drought and compete with weeds. Women rice farmers are mostly tasked with weeding activity in the field.

MDG4 – Reduce child mortality

The same survey referred to above (MDG2) revealed:

- a 2% reduction in the frequency of child sickness in these families
- a 5% increase in attendance at hospital when children fell sick
- about USD 12 increase in family spending on child healthcare

Better harvests with more yield put extra cash in NERICA farmers' pockets to fund schooling, medical care and better diet.

MDG5 – Improve maternal health

The protein content of some of the NERICA varieties has been found to be 25% higher (average of 10% protein for these NERICA lines vs. 8% for Asian rice in the world market). As the NERICA varieties have higher protein content than other rice varieties and are more nutritious than many of the traditional staples, farmers growing NERICAs have improved their diets. An improved diet leads to better health and there is a greater chance that a healthy mother will give birth to a healthy child than a weakened mother.

MDG6 – Combat HIV/AIDS, malaria and other diseases

As the largest employer in SSA, agriculture is particularly affected by HIV/AIDS. This places a greater burden on the surviving farmers which can be eased by the introduction of improved crop varieties.

For example, the high yielding NERICA varieties are also early maturing and thereby lessen the labor burden.

The CGIAR Systemwide Initiative on HIV/AIDS and Agriculture (SWIHA) is promoting NERICA technology as part of its program to mitigate the effects of the pandemic on farmers.

MDG7 – Ensure environmental sustainability

Benefits from NERICA varieties lie not only in improved food security, better diets and higher incomes for resource-limited farmers but also through less pressure on the environment. Since some of the NERICA varieties seem to cope well with less water in drought-prone environments, farmers may no longer have to practice slash-and-burn agriculture.

MDG8 – Develop a global partnership for development

Rice imports are draining more than USD 1 billion from precious foreign exchange reserves in SSA. Projections by WARDA show that a 20% increase in NERICA planting in SSA countries could result in a 5% reduction in the rice import bill. A range of partnership models including work with advanced universities, NARES and donors is being explored to accelerate NERICA dissemination. In 2006 it was estimated that about 200,000 hectares were under upland NERICA production in SSA.

NERICA FOOD PREPARATION: FROM PLANT TO PLATE

Contributors: Modesta Brym Akintayo and Inoussa Akintayo

Background

The performance of NERICA-based processed products suggests NERICA-sourced flour can efficiently substitute for wheat flour in many confectioneries. The process of preparing selected NERICA-based products is summarized below.





Preparation of selected NERICA-based products

How to get NERICA flour?

Mill NERICA grain (whole or broken grains) into flour
Sieve in a fine mesh strainer

Butter cookies

Ingredients:

250 g of rice flour
125 g of sugar
2 sachets of vanilla sugar
3 or 4 eggs

Preparation: pre-heat oven to 150 degrees Celsius

- ✓ Add butter to sugar and beat into a smooth cream
- ✓ Add eggs one by one and continue beating for smoothness
- ✓ Mix flour and vanilla sugar, and add mixture to cream
- ✓ Mix all into a smooth paste and set dough in cookie molds
- ✓ Bake in oven for 15 minutes until it starts to brown

Cocoa biscuits

Ingredients:

200 g of rice flour
3 spoons of unsweetened cocoa
100 g of butter
150 g of sugar
3 or 4 eggs (y)
3 sachets of vanilla sugar

Preparation: pre-heat oven to 150 degrees Celsius

- ✓ Thoroughly mix the flour, cocoa and vanilla sugar
- ✓ Mix butter and sugar into a smooth cream
- ✓ Mix the flour and cream into a smooth paste
- ✓ Distribute paste into biscuit molds and bake in oven for 15 minutes until they start to brown

Ginger biscuits

Ingredients:

300 g of rice flour
125 g of sugar
125 g of butter
3 to 4 eggs
4 tablespoons of grated ginger
2 teaspoons of baking powder
1 teaspoon of bicarbonate
2 teaspoons of milk powder

Preparation: pre-heat oven to 150 degrees Celsius

- ✓ Mix flour and butter
- ✓ Add baking powder and sugar
- ✓ Beat eggs and add to mixture while stirring to avoid lumps
- ✓ Stir the ginger into the paste
- ✓ Mix milk and bicarbonate, pour it all on the paste and mix thoroughly
- ✓ Knead paste into shape by hand
- ✓ Flatten paste into the required thickness and cut
- ✓ Bake in oven for 15 to 20 minutes

Pancakes

Ingredients:

300 g of rice flour

1 liter of milk

100g of sugar

6 eggs

Vanilla or lemon zest

Preparation:

- ✓ Whip eggs and sugar into a mousse mixture
- ✓ Pour mixture on flour and mix until smooth
- ✓ Pour milk on mixture and continue mixing until smooth
- ✓ Add a little vanilla or lemon zest
- ✓ Leave the resulting batter to settle for six hours, preferably in a cooler

Baking:

- ✓ Heat a pancake pan
- ✓ Oil pan with a teaspoonful of oil
- ✓ Pour a ladleful of batter into pan
- ✓ For best results, toss the pancake after 3 minutes to brown both sides
- ✓ Repeat until the batter is used up

Serve with honey or jam

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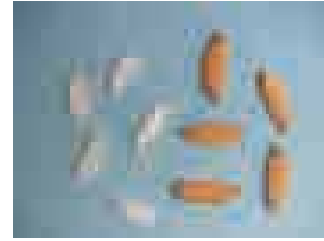
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NERICA1



1. IDENTIFICATION

- 1.1 Synonym: WAB 450 – I - B – P – 38 – HB
- 1.2 Species: *Oryza sativa* × *Oryza glaberrima*
- 1.3 Varietal type: NERICA®
- 1.4 Parents: WAB 56 – 104 / CG 14
- 1.5 Genetic nature: Pure line
- 1.6 Geographical origin: WARDA, Bouaké
- 1.7 Development: 1994

2. AGRONOMIC CHARACTERISTICS

- 2.1 Ecology: Upland rice
- 2.2 Days to 50% heading: 70–75 days
- 2.3 Maturity: 95-100 days
- 2.4 Potential yield: 4500 kg/ha
- 2.5 1000 grains weight: 29.0 g
- 2.6 Resistance to leaf blast: Medium
- 2.7 Resistance to insects: Good
- 2.8 Resistance to lodging: Good

3. MORPHOLOGICAL CHARACTERISTICS

3.1 Plant

- Average height: 100 cm
- Tillering: Good
- Basal leaf sheath color: Purple
- Leaf angle: Erect
- Flag leaf angle: Erect

3.2 Panicle

- Type: Compact
- Exsertion: Good

3.3 Grain

Length: 6.9 mm

Width: 2.6 mm

Size: Medium

Lemma color: Light fawn with black apex

Awning: Absent

Apex color: Black/purple

Caryopsis color: White

4. ORGANOLEPTIC AND TECHNOLOGICAL CHARACTERISTICS

4.1 Amylose content: 26.6 %

4.2 Milling rate: 63 %

4.3 Cooking quality: Good

4.4 Aroma: Perfume

5. CULTURAL PRACTICES

Contact your Country Extension Services



NERICA2



1. IDENTIFICATION

- 1.1 Synonym: WAB 450-11-1-P31-1-HB
- 1.2 Species: *Oryza sativa* × *Oryza glaberrima*
- 1.3 Varietal type: NERICA®
- 1.4 Parents: WAB 56 – 104 / CG 14
- 1.5 Genetic nature: Pure line
- 1.6 Geographical origin: WARDA, Bouaké
- 1.7 Development: 1994

2. AGRONOMIC CHARACTERISTICS

- 2.1 Ecology: Upland rice
- 2.2 Days to 50% heading: 65–70 days
- 2.3 Maturity: 90–95 days
- 2.4 Potential yield: 4000 kg/ha
- 2.5 1000 grains weight: 26.0 g
- 2.6 Resistance to leaf blast: Resistant
- 2.7 Resistance to insects: Good
- 2.8 Resistance to lodging: Good

3. MORPHOLOGICAL CHARACTERISTICS

- 3.1 Plant
 - Average height: 100 cm
 - Tillering: Good
 - Basal leaf sheath color: Green
 - Leaf angle: Erect
 - Flag leaf angle: Erect
- 3.2 Panicle
 - Type: Compact
 - Exsertion: Good

3.3 Grain

Length: 6.9 mm

Width: 2.3 mm

Size: Medium

Lemma color: Light fawn

Awning: Awned

Apex color: Black/purple

Caryopsis color: White

4. ORGANOLEPTIC AND TECHNOLOGICAL CHARACTERISTICS

4.1 Amylose content: 26.4%

4.2 Milling rate: 62%

4.3 Cooking qualities: Good

4.4 Aroma: None

5. CULTURAL PRACTICES

Contact your Country Extension Services



NERICA3



1. IDENTIFICATION

- 1.1 Synonym: WAB 450-I-B-P-28-HB
- 1.2 Species: *Oryza sativa* × *Oryza glaberrima*
- 1.3 Varietal type: NERICA®
- 1.4 Parents: WAB 56 – 104 / CG 14
- 1.5 Genetic nature: Pure line
- 1.6 Geographical origin: WARDA, Bouaké
- 1.7 Development: 1994

2. AGRONOMIC CHARACTERISTICS

- 2.1 Ecology: Upland rice
- 2.2 Days to 50% heading: 70–75 days
- 2.3 Maturity: 95–100 days
- 2.4 Potential yield: 4500 kg/ha
- 2.5 1000 grains weight: 29.0 g
- 2.6 Resistance to leaf blast: Medium
- 2.7 Resistance to insects: Good
- 2.8 Resistance to lodging: Good

3. MORPHOLOGICAL CHARACTERISTICS

- 3.1 Plant
 - Average height: 110 cm
 - Tillering: Good
 - Basal leaf sheath color: Light green
 - Leaf angle: Erect
 - Flag leaf angle: Erect
- 3.2 Panicle
 - Type: A bit open
 - Exsertion: Good

3.3 Grain

Length: 7.2 mm

Width: 2.2 mm

Size: Long

Lemma color: Dark fawn

Awning: Absent

Apex color: None

Caryopsis color: White

4. ORGANOLEPTIC AND TECHNOLOGICAL CHARACTERISTICS

4.1 Amylose content: 23.8%

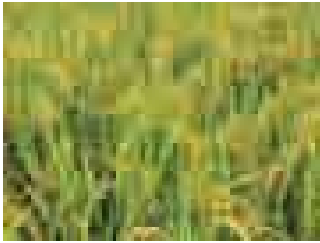
4.2 Milling rate: 63%

4.3 Cooking qualities: Good

4.4 Aroma: None

5. CULTURAL PRACTICES

Contact your Country Extension Services



NERICA4



1. IDENTIFICATION

- 1.1 Synonym: WAB 450-I-B-P-91-HB
- 1.2 Species: *Oryza sativa* × *Oryza glaberrima*
- 1.3 Varietal type: NERICA®
- 1.4 Parents: WAB 56 – 104 / CG 14

2. AGRONOMIC CHARACTERISTICS

- 2.1 Ecology: Upland rice
- 2.2 Days to 50% heading: 70–75 days
- 2.3 Maturity: 95–00 days
- 2.4 Potential yield: 5000 kg/ha
- 2.5 1000 grains weight: 29.0 g
- 2.6 Resistance to leaf blast: Medium
- 2.7 Resistance to insects: Good
- 2.8 Resistance to lodging: Good

3. MORPHOLOGICAL CHARACTERISTICS

3.1 Plant

- Average height: 120 cm
- Tillering: Good
- Basal leaf sheath color: Light green
- Leaf angle: Erect
- Flag leaf angle: Erect

3.2 Panicle

- Type: Compact
- Exsertion: Good

3.3 Grain

Length: 7.2 mm

Width: 2.5 mm

Size: Long

Lemma color: Fawn

Awning: Absent

Apex color: None

Caryopsis color: White

4.ORGANOLEPTIC AND TECHNOLOGICAL CHARACTERISTICS

4.1 Amylose content: 23%

4.2 Milling rate: 63%

4.3 Cooking qualities: Good

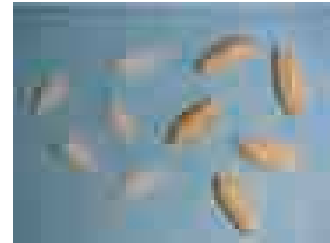
4.4 Aroma: None

5. CULTURAL PRACTICES

Contact your Country Extension Services



NERICA6



1. IDENTIFICATION

- 1.1 Synonym: WAB 450-I-B-P-160-HB
- 1.2 Species: *Oryza sativa* × *Oryza glaberrima*
- 1.3 Varietal type: NERICA®
- 1.4 Parents: WAB 56 – 104 / CG 14
- 1.5 Genetic nature: Pure line
- 1.6 Geographical origin: WARDA, Bouaké
- 1.7 Development: 1994

2. AGRONOMIC CHARACTERISTICS

- 2.1 Ecology: Upland rice
- 2.2 Days to 50% heading: 70–75 days
- 2.3 Maturity: 95–100 days
- 2.4 Potential yield: 5000 kg/ha
- 2.5 1000 grains weight: 29.0 g
- 2.6 Resistance to leaf blast: Resistant
- 2.7 Resistance to insects: Good
- 2.8 Resistance to lodging: Good

3. MORPHOLOGICAL CHARACTERISTICS

- 3.1 Plant
 - Average height: 130 cm
 - Tillering: Good
 - Basal leaf sheath color: Light green
 - Leaf angle: Erect
 - Flag leaf angle Erect
- 3.2 Panicle
 - Type: Compact
 - Exsertion: Good

3.3 Grain

Length: 6.2 mm

Width: 2.8 mm

Size: Medium

Lemma color: Straw

Awning: Absent

Apex color: None

Caryopsis color: White

4.ORGANOLEPTIC AND TECHNOLOGICAL CHARACTERISTICS

4.1 Amylose content: 24.5%

4.2 Milling rate: 63%

4.3 Cooking qualities: Good

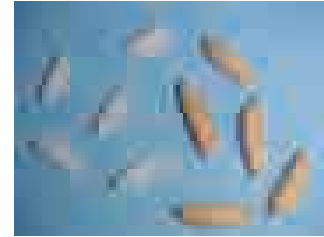
4.4 Aroma: None

5. CULTURAL PRACTICES

Contact your Country Extension Services



NERICA7



1. IDENTIFICATION

- 1.1 Synonym: WAB 450-I-B-P-20-HB
- 1.2 Species: *Oryza sativa* × *Oryza glaberrima*
- 1.3 Varietal type: NERICA®
- 1.4 Parents: WAB 56 – 104 / CG 14
- 1.5 Genetic nature: Pure line
- 1.6 Geographical origin: WARDA, Bouaké
- 1.7 Development: 1994

2. AGRONOMIC CHARACTERISTICS

- 2.1 Ecology: Upland rice
- 2.2 Days to 50% heading: 70–75 days
- 2.3 Maturity: 95–100 days
- 2.4 Potential yield: 5000 kg/ha
- 2.5 1000 grains weight: 33.0 g
- 2.6 Resistance to leaf blast: Medium
- 2.7 Resistance to insects: Good
- 2.8 Resistance to lodging: Good

3. MORPHOLOGICAL CHARACTERISTICS

- 3.1 Plant
 - Average height: 130 cm
 - Tillering: Good
 - Basal leaf sheath color: Light green
 - Leaf angle: Erect
 - Flag leaf angle: Erect
- 3.2 Panicle
 - Type: Compact
 - Exsertion: Good

3.3 Grain

Length: 7.3 mm

Width: 2.6 mm

Size: Long

Lemma color: Straw

Awning: Absent

Apex color: None

Caryopsis color: White

4. ORGANOLEPTIC AND TECHNOLOGICAL CHARACTERISTICS

4.1 Amylose content: 27.8%

4.2 Milling rate: 63%

4.3 Cooking qualities: Good

4.4 Aroma: None

5. CULTURAL PRACTICES

Contact your Country Extension Services



NERICA8



1. IDENTIFICATION

- 1.1 Synonym: WAB 450 – 1 – BL1 – 136 – HB
- 1.2 Species: *Oryza sativa* × *Oryza glaberrima*
- 1.3 Varietal type: NERICA®
- 1.4 Parents: WAB 56 – 104 / CG 14
- 1.5 Genetic nature: Pure line
- 1.6 Geographical origin: WARDA, Bouaké
- 1.7 Development: 1994

2. AGRONOMIC CHARACTERISTICS

- 2.1 Ecology: Upland rice
- 2.2 Days to 50% heading: 55–60 days
- 2.3 Maturity: 75–85 days
- 2.4 Potential yield: 5000 kg/ha
- 2.5 1000 grains weight: 29.0 g
- 2.6 Resistance to leaf blast: Good
- 2.7 Resistance to insects: Good
- 2.8 Resistance to lodging: Moderate

3. MORPHOLOGICAL CHARACTERISTICS

3.1 Plant

- Average height: 100 cm
- Tillering: Good
- Basal leaf sheath color: Light green
- Leaf angle: Erect
- Flag leaf angle: Erect

3.2 Panicle

- Type: Compact
- Exsertion: Good

3.3 Grain

Length: 7.0 mm

Width: 2.6 mm

Size: Medium

Lemma color: Fawn

Awning: Absent

Apex color: light brown

Caryopsis color: White

4.ORGANOLEPTIC AND TECHNOLOGICAL CHARACTERISTICS

4.1 Amylose content: 26.5%

4.2 Milling rate: 70%

4.3 Cooking quality: Good

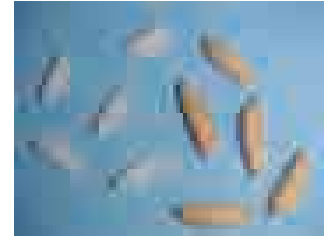
4.4 Aroma: None but smell at flowering stage

5. CULTURAL PRACTICES

Contact your Country Extension Services



NERICA9



1. IDENTIFICATION

- 1.1 Synonym: WAB 450 – B – 136 – HB
- 1.2 Species: *Oryza sativa* × *Oryza glaberrima*
- 1.3 Varietal type: NERICA®
- 1.4 Parents: WAB 5 6 – 104 / CG 14
- 1.5 Genetic nature: Pure line
- 1.6 Geographical origin: WARDA, Bouaké
- 1.7 Development: 1994

2. AGRONOMIC CHARACTERISTICS

- 2.1 Ecology: Upland rice
- 2.2 Days to 50% heading: 55–60 days
- 2.3 Maturity: 75–85 days
- 2.4 Potential yield: 5000 kg/ha
- 2.5 1000 grains weight: 29.4 g
- 2.6 Resistance to leaf blast: Good
- 2.7 Resistance to insects: Good
- 2.8 Resistance to lodging: Moderate

3. MORPHOLOGICAL CHARACTERISTICS

- 3.1 Plant
 - Average height: 105 cm
 - Tillering: Good
 - Basal leaf sheath color: Light green
 - Leaf angle: Erect
 - Flag leaf angle: Erect
- 3.2 Panicle
 - Type: Compact
 - Exsertion: Good

3.3 Grain

Length: 6.8 mm

Width: 2.3 mm

Size: Medium

Lemma color: Fawn

Awning: Absent

Apex color: light brown

Caryopsis color: White

4. ORGANOLEPTIC AND TECHNOLOGICAL CHARACTERISTICS

4.1 Milling rate: 62%

4.2 Cooking quality: Good

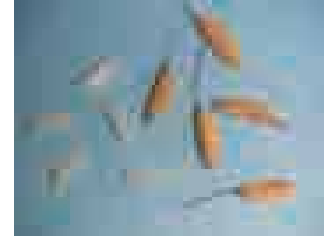
4.3 Aroma: None but smell at flowering stage

5. CULTURAL PRACTICES

Contact your Country Extension Services



NERICA10



1. IDENTIFICATION

- 1.1 Synonym: WAB 450 – 11-1- 1 – P41 – HB
- 1.2 Species: *Oryza sativa* × *Oryza glaberrima*
- 1.3 Varietal type: NERICA®
- 1.4 Parents: WAB 56 – 104 / CG 14
- 1.5 Genetic nature: Pure line
- 1.6 Geographical origin: WARDA, Bouaké
- 1.7 Development: 1994

2. AGRONOMIC CHARACTERISTICS

- 2.1 Ecology: Upland rice
- 2.2 Days to 50% heading: 65–70 days
- 2.3 Maturity: 90–100 days
- 2.4 Potential yield: 6000 kg/ha
- 2.5 1000 grains weight: 28.7 g
- 2.6 Resistance to leaf blast: Good
- 2.7 Resistance to insects: Good
- 2.8 Resistance to lodging: Moderate

3. MORPHOLOGICAL CHARACTERISTICS

3.1 Plant

- Average height: 110 cm
- Tillering: Good
- Basal leaf sheath color: Green
- Leaf angle: Erect
- Flag leaf angle: Erect

3.2 Panicle

- Type: Compact
- Exsertion: Good

3.3 Grain

Length: 6.6 mm

Width: 2.3 mm

Size: Medium

Lemma color: Light fawn

Awning: Awned

Apex color: Black/purple

Caryopsis color: White

4. ORGANOLEPTIC AND TECHNOLOGICAL CHARACTERISTICS

4.1 Milling rate: 63 %

4.2 Cooking quality: Good

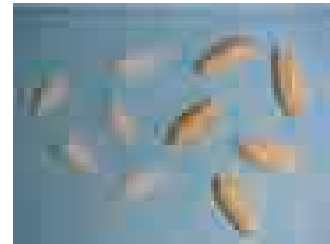
4.3 Aroma: None but smell at flowering stage

5. CULTURAL PRACTICES

Contact your Country Extension Services



NERICA11



1. IDENTIFICATION

- 1.1 Synonym: WAB 450 – 16- 2 – BL2 – DV1
- 1.2 Species: *Oryza sativa* × *Oryza glaberrima*
- 1.3 Varietal type: NERICA®
- 1.4 Parents: WAB 56 – 104 / CG 14
- 1.5 Genetic nature: Pure line
- 1.6 Geographical origin: WARDA, Bouaké
- 1.7 Development: 1994

2. AGRONOMIC CHARACTERISTICS

- 2.1 Ecology: Upland rice
- 2.2 Days to 50% heading: 55–60 days
- 2.3 Maturity: 75–85 days
- 2.4 Potential yield: 7000 kg/ha
- 2.5 1000 grains weight: 28.4 g
- 2.6 Resistance to leaf blast: Good
- 2.7 Resistance to insects: Good
- 2.8 Resistance to lodging: Moderate

3. MORPHOLOGICAL CHARACTERISTICS

3.1 Plant

- Average height: 105 cm
- Tillering: Good
- Basal leaf sheath color: Light green
- Leaf angle: Erect
- Flag leaf angle: Erect

3.2 Panicle

- Type: Compact
- Exsertion: Good

3.3 Grain

Length: 7.0 mm

Width: 2.4 mm

Size: Medium

Lemma color: Light fawn

Awning: Awned

Apex Color: Black/purple

Caryopsis color: White

4. ORGANOLEPTIC AND TECHNOLOGICAL CHARACTERISTICS

4.1 Milling rate: 65 %

4.2 Cooking quality: Good

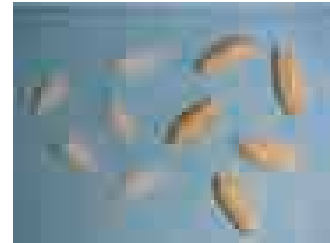
4.3 Aroma: None but smell at flowering stage

5. CULTURAL PRACTICES

Contact your Country Extension Services



NERICA12



1. IDENTIFICATION

- 1.1 Synonym: WAB 880 – 1 –38- 20-17–P1- HB
- 1.2 Species: *Oryza sativa* × *Oryza glaberrima*
- 1.3 Varietal type: NERICA®
- 1.4 Parents: WAB 56 – 50 / CG 14
- 1.5 Genetic nature: Pure line
- 1.6 Geographical origin: WARDA, Bouaké
- 1.7 Development: 1994

2. AGRONOMIC CHARACTERISTICS

- 2.1 Ecology: Upland rice
- 2.2 Days to 50% heading: 65–70 days
- 2.3 Maturity: 90–100 days
- 2.4 Potential yield: 5500 kg/ha
- 2.5 1000 grains weight: 36.8 g
- 2.6 Resistance to leaf blast: Good
- 2.7 Resistance to insects: Good
- 2.8 Resistance to lodging: Moderate

3. MORPHOLOGICAL CHARACTERISTICS

3.1 Plant

- Average height: 115 cm
- Tillering: Good
- Basal leaf sheath color: Light green
- Leaf angle: Erect
- Flag leaf angle: Erect

3.2 Panicle

- Type: Compact
- Exsertion: Good

3.3 Grain

Length: 7.2 mm

Width: 2.5 mm

4. ORGANOLEPTIC AND TECHNOLOGICAL CHARACTERISTICS

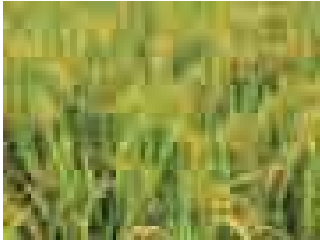
4.1 Milling rate: 63 %

4.2 Cooking quality: Good

4.3 Aroma: None

5. CULTURAL PRACTICES

Contact your Country Extension Services



NERICA13



1. IDENTIFICATION

- 1.1 Synonym: WAB 880 – 1 – 38-20-28-P1 – HB
- 1.2 Species: *Oryza sativa* × *Oryza glaberrima*
- 1.3 Varietal type: NERICA®
- 1.4 Parents: WAB 56 – 50 / CG 14
- 1.5 Genetic nature: Pure line
- 1.6 Geographical origin: WARDA, Bouaké
- 1.7 Development: 1994

2. AGRONOMIC CHARACTERISTICS

- 2.1 Ecology: Upland rice
- 2.2 Days to 50% heading: 65 days
- 2.3 Maturity: 90–100 days
- 2.4 Potential yield: 6000 kg/ha
- 2.5 1000 grains weight: 32.9 g
- 2.6 Resistance to leaf blast: Good
- 2.7 Resistance to insects: Good
- 2.8 Resistance to lodging: Moderate

3. MORPHOLOGICAL CHARACTERISTICS

3.1 Plant

- Average height: 120 cm
- Tillering: Good
- Basal leaf sheath color: Light green
- Leaf angle: Erect
- Flag leaf angle: Erect

3.2 Panicle

- Type: Compact
- Exsertion: Good

3.3 Grain

Length: 7.2 mm

Width: 2.4 mm

Size: Long

Lemma color: Fawn

Awning: Absent

Apex color: None

Caryopsis color: White

4. ORGANOLEPTIC AND TECHNOLOGICAL CHARACTERISTICS

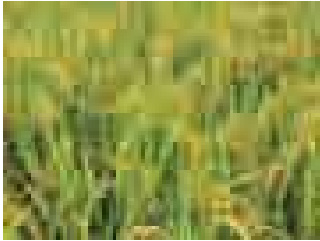
4.1 Milling rate: 63 %

4.2 Cooking quality: Good

4.3 Aroma: None

5. CULTURAL PRACTICES

Contact your Country Extension Services

**NERICA14**

1. IDENTIFICATION

- 1.1 Synonym: WAB 880 – 1 – 32-1-2-P1-HB
- 1.2 Species: *Oryza sativa* × *Oryza glaberrima*
- 1.3 Varietal type: NERICA®
- 1.4 Parents: WAB 56 – 50 / CG 14
- 1.5 Genetic nature: Pure line
- 1.6 Geographical origin: WARDA, Bouaké
- 1.7 Development: 1994

2. AGRONOMIC CHARACTERISTICS

- 2.1 Ecology: Upland rice
- 2.2 Days to 50% heading: 55–60 days
- 2.3 Maturity: 75–85 days
- 2.4 Potential yield: 5000 kg/ha
- 2.5 1000 grains weight: 33.6 g
- 2.6 Resistance to leaf blast: Good
- 2.7 Resistance to insects: Good
- 2.8 Resistance to lodging: Moderate

3. MORPHOLOGICAL CHARACTERISTICS

3.1 Plant

- Average height: 110 cm
- Tillering: Good
- Basal leaf sheath color: Light green
- Leaf angle: Erect
- Flag leaf angle: Erect

3.2 Panicle

- Type: Compact
- Exsertion: Good

3.3 Grain

Length: 7.3 mm

Width: 2.4 mm

Size: Long

Lemma color: Fawn

Awning: Absent

Apex color: Brown

Caryopsis color: Reddish

4. ORGANOLEPTIC AND TECHNOLOGICAL CHARACTERISTICS

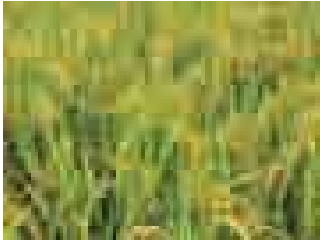
4.1 Milling rate: 63 %

4.2 Cooking quality: Good

4.3 Aroma: None

5. CULTURAL PRACTICES

Contact your Country Extension Services



NERICA15



1. IDENTIFICATION

- 1.1 Synonym: WAB 881 – 10 – 37-18-3-P1 – HB
- 1.2 Species: *Oryza glaberrima* × *Oryza sativa*
- 1.3 Varietal type: NERICA®
- 1.4 Parents: CG 14/WAB 181-18
- 1.5 Genetic nature: Pure line
- 1.6 Geographical origin: WARDA, Bouaké
- 1.7 Development: 1994

2. AGRONOMIC CHARACTERISTICS

- 2.1 Ecology: Upland rice
- 2.2 Days to 50% heading: 60–70 days
- 2.3 Maturity: 90–100 days
- 2.4 Potential yield: 5000 kg/ha
- 2.5 1000 grains weight: 29.0 g
- 2.6 Resistance to leaf blast: Good
- 2.7 Resistance to insects: Good
- 2.8 Resistance to lodging: Moderate

3. MORPHOLOGICAL CHARACTERISTICS

3.1 Plant

- Average height: 130 cm
- Tillering: Good
- Basal leaf sheath color: Light green
- Leaf angle: Erect
- Flag leaf angle: Erect

3.2 Panicle

- Type: Compact
- Exsertion: Good

3.3 Grain

Length: 7.2 mm

Width: 2.4 mm

Size: Long

Lemma color: Straw

Awning: Absent

Apex color: None

Caryopsis color: Red

4. ORGANOLEPTIC AND TECHNOLOGICAL CHARACTERISTICS

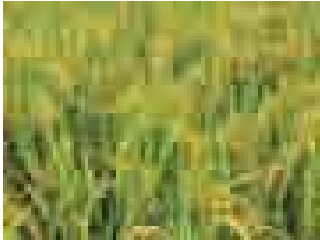
4.1 Milling rate: 63 %

4.2 Cooking quality: Good

4.3 Aroma: None

5. CULTURAL PRACTICES

Contact your Country Extension Services

**NERICA16**

1. IDENTIFICATION

- 1.1 Synonym: WAB 881 – 10 – 37-18-9-P1 – HB
- 1.2 Species: *Oryza glaberrima* × *Oryza sativa*
- 1.3 Varietal type: NERICA®
- 1.4 Parents: CG 14 / WAB 181-18
- 1.5 Genetic nature: Pure line
- 1.6 Geographical origin: WARDA, Bouaké
- 1.7 Development: 1994

2. AGRONOMIC CHARACTERISTICS

- 2.1 Ecology: Upland rice
- 2.2 Days to 50% heading: 60–70 days
- 2.3 Maturity: 90–100 days
- 2.4 Potential yield: 6000 kg/ha
- 2.5 1000 grains weight: 29.2 g
- 2.6 Resistance to leaf blast: Good
- 2.7 Resistance to insects: Good
- 2.4 Potential yield: 6000 kg/ha
- 2.8 Resistance to lodging: Moderate

3. MORPHOLOGICAL CHARACTERISTICS

- 3.1 Plant
 - Average height: 130 cm
 - Tillering: Good
 - Basal leaf sheath color: Light green
 - Leaf angle: Erect
 - Flag leaf angle: Erect

3.2 Panicle

Type: Compact

Exsertion: Good

3.3 Grain

Length: 7.1 mm

Width: 2.4 mm

Size: Long

Lemma color: Straw

Awning: Absent

Apex color: None

Caryopsis color: Red

4. ORGANOLEPTIC AND TECHNOLOGICAL CHARACTERISTICS

4.1 Milling rate: 64 %

4.2 Cooking quality: Good

4.3 Aroma: None

5. CULTURAL PRACTICES

Contact your Country Extension Services



NERICA17



1. IDENTIFICATION

- 1.1 Synonym: WAB 881 – 10 – 37-18-13-P1 – HB
- 1.2 Species: *Oryza glaberrima* × *Oryza sativa*
- 1.3 Varietal type: NERICA®
- 1.4 Parents: CG 14/WAB 181-18
- 1.5 Genetic nature: Pure line
- 1.6 Geographical origin: WARDA, Bouaké
- 1.7 Development: 1994

2. AGRONOMIC CHARACTERISTICS

- 2.1 Ecology: Upland rice
- 2.2 Days to 50% heading: 60–70 days
- 2.3 Maturity: 90–100 days
- 2.4 Potential yield: 6500 kg/ha
- 2.5 1000 grains weight: 35.1 g
- 2.6 Resistance to leaf blast: Good
- 2.7 Resistance to insects: Good
- 2.8 Resistance to lodging: Moderate

3. MORPHOLOGICAL CHARACTERISTICS

- 3.1 Plant
 - Average height: 115 cm
 - Tillering: Good
 - Basal leaf sheath color: Light green
 - Leaf angle: Erect
 - Flag leaf angle: Erect
- 3.2 Panicle
 - Type: Compact
 - Exsertion: Good

3.3 Grain

Length: 7.4 mm

Width: 2.6 m

Size: Medium

Lemma color: Fawn

Awning: Absent

Apex color: Brown

Caryopsis color: White

4. ORGANOLEPTIC AND TECHNOLOGICAL CHARACTERISTICS

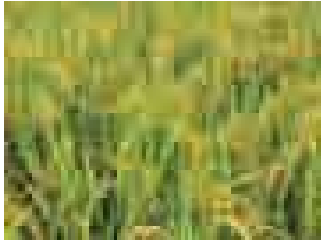
4.1 Milling rate: 63 %

4.2 Cooking quality: Good

4.3 Aroma: None

5. CULTURAL PRACTICES

Contact your Country Extension Services

**NERICA18**

1. IDENTIFICATION

- 1.1 Synonym: WAB 881 – 10 – 37-18-12 – P3 – HB
- 1.2 Species: *Oryza glaberrima* × *Oryza sativa*
- 1.3 Varietal type: NERICA®
- 1.4 Parents: CG 14 / WB 181-18

2. AGRONOMIC CHARACTERISTICS

- 2.1 Ecology: Upland rice
- 2.2 Days to 50% heading: 60–70 days
- 2.3 Maturity: 90–100 days
- 2.4 Potential yield: 5000 kg/ha
- 2.5 1000 grains weight: 32.3 g
- 2.6 Resistance to leaf blast: Good
- 2.7 Resistance to insects: Good
- 2.8 Resistance to lodging: Moderate

3. MORPHOLOGICAL CHARACTERISTICS

3.1 Plant

- Average height: 130 cm
- Tillering: Good
- Basal leaf sheath color: Light green
- Leaf angle: Erect
- Flag leaf angle: Erect

3.2 Panicle

- Type: Compact
- Exsertion: Good

3.3 Grain

Length: 7.4 mm

Width: 2.3 mm

Size: Long

Lemma color: Straw

Awning: Absent

Apex color: None

Caryopsis color: Red

4. ORGANOLEPTIC AND TECHNOLOGICAL CHARACTERISTICS

4.1 Milling rate: 63 %

4.2 Cooking quality: Good

4.3 Aroma: None

5. CULTURAL PRACTICES

Contact your Country Extension Services

Do you have any comments on this book that you wish to share with the authors?

Have you conducted research relevant to NERICA[®] that might usefully be included in future editions of this compendium?

Please copy this page and fill in details of your question or comment and send it to the following address:

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