Development of New Rice for Africa (NERICA) and participatory varietal selection

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Abstract

One of the major research thrusts of the West African Rice Development Association (WARDA) to meet the ever-increasing demand for rice in West and Central Africa (WCA) has been the development of higher yielding varieties. By 1996 WARDA had developed a range of new interspecific varieties derived from crosses between the Asian rice, *Oryza sativa* and the African rice *O. glaberrima*. These varieties, later termed NERICAs (New Rice for Africa), have shown a stable and high yield and tolerance to major biophysical production constraints in a range of upland environments. Their rapid dissemination to small rice farmers in WCA has been achieved through participatory varietal selection (PVS), an applied and adaptive research mechanism in which farmers play an active role in varietal selection, development and spread. PVS lasts for three years during which farmers select and evaluate varieties on their own farms. PVS was initiated in Côte d'Ivoire in 1996 and by 2000 all 17 WARDA member countries had initiated PVS involving 4000 farmers at 105 sites. Particular progress has been made in Guinea where from 1997 to 2000 the number of farmers participating in PVS rose from 116 to 20,000 the area sown to NERICAs from 50 to 8,000 hectares.

Introduction

Demand for rice in West and Central Africa (WCA) has been growing at the rate of 6% per annum since 1973, and now amounts to over 8 million tonnes per annum. Increased consumption is due both to population growth (average of 2.9% per annum) and to the increased share of rice in the diet of the African population.

Over the same period, production of rice has been expanding at the rate of 5.1% per annum, with 70% of the growth due to an increased area of cultivated rice, but only 30% due to higher yields. Much of the expansion has been in the rainfed systems, particularly the two major ecosystems that make up 78% of rice land in WCA: namely, the upland and rainfed lowland systems.

To cover the increasing gap between rice demand and supply, rice is being imported at an increasing rate. Shipments of rice to Africa rose by 11% to slightly more than 5 million tonnes in 1999/2000; Nigeria being the major importer at 0.9 million tons, closely followed by Côte d'Ivoire. The cost of this importation is around $1 billion of foreign exchange each year.

With population growth rate exceeding that of regional food production, and limited foreign exchange for increased levels of imports, the future for Africa's poor appears grim. For food security, WCA needs to increase production capacity for when cheap rice can no longer be imported.

The birth of a new rice for Africa

The Asian rice *Oryza sativa* was brought to Africa over 500 years ago. Within a short period, because of its high yield potential, it replaced most of the indigenous African rice, *Oryza glaberrima*, which was pushed to inhospitable, scraggy and infertile upland soils or flood-prone inland valleys and deltas. In Africa, however, *O. sativa* suffered attack by pests and diseases known only to the African continent. Toxic soils with limited nutrients also reduced its yield potential. The hardy African rice, *O. glaberrima*, with a history of 3,500 years of cultivation, withstands these problems better than O. sativa. To combine the best traits of the Asian and African rice species, the challenge is to transfer into the heavy yielding but stress-prone *O. sativa* the desirable genes in *O. glaberrima* while shedding its undesirable traits of lodging, fewer grains and grain shattering.

Conventional breeding efforts to develop interspecific hybrids had failed due to a high level of sterility of the hybrids. In 1991, WARDA launched a new effort to combine the genetic potential of the two rice species, using conventional and anther culture 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.

The generous support of donors in Japan and the Rockerfeller Foundation in the USA to the Joint Interspecific Hybridization Project allowed considerable progress to be made, and by the late 1990s interspecific lines of a radically different plant type, tailored for dryland rice farmers of West and Central Africa, had been developed and were being tested and evaluated in a range of environments.

Agronomic characteristics of interspecific lines

Since the mid-1990s many interspecific lines have been generated, evaluated and characterised for a range of agronomic traits and reaction to important diseases and pests (WARDA 1999, 2000, and 2001). In 2000, the interspecific lines were dubbed NERICA (New Rice for Africa).

NERICAs have been identified with one or more of the following characteristics:

- Wide and droopy leaves that help to smother leaves in early growth.
- Strong stems that can support heavy heads of grain.
- More tillers with longer grain-bearing panicles than either parent and non-shattering grains.
- Stems with secondary branches on their panicles that can carry up to 400 grains.
- Early maturity, 30-50 days earlier than currently grown cultivars.
- A good height that allows easy harvest of panicles.
- Good tolerance to drought.
- Resistance or tolerance to Africa's most serious pests and diseases - African rice gall midge, rice yellow mottle virus and blast (*Magnaporthe grisea*).
- Tolerance to acidic soils but responsive to limited organic and inorganic fertilizers.

NERICAs have shown stable yields under both low- and high-input conditions and are expected to reduce risk and increase productivity in farmers' fields, thereby reducing the need to clear new land. Reduced risk will also give farmers incentives to use more inputs, intensify land use, and gradually abandon shifting cultivation, thus improving system sustainability. The rapid introduction of NERICAs to small farmers in WAC was, therefore, considered a vitally important first step towards the sustainable intensification of Africa's fragile uplands. The NERICAs were not intended as a total replacement for local varieties for integrating into the existing varietal portfolio of farmers.

PVS methodology

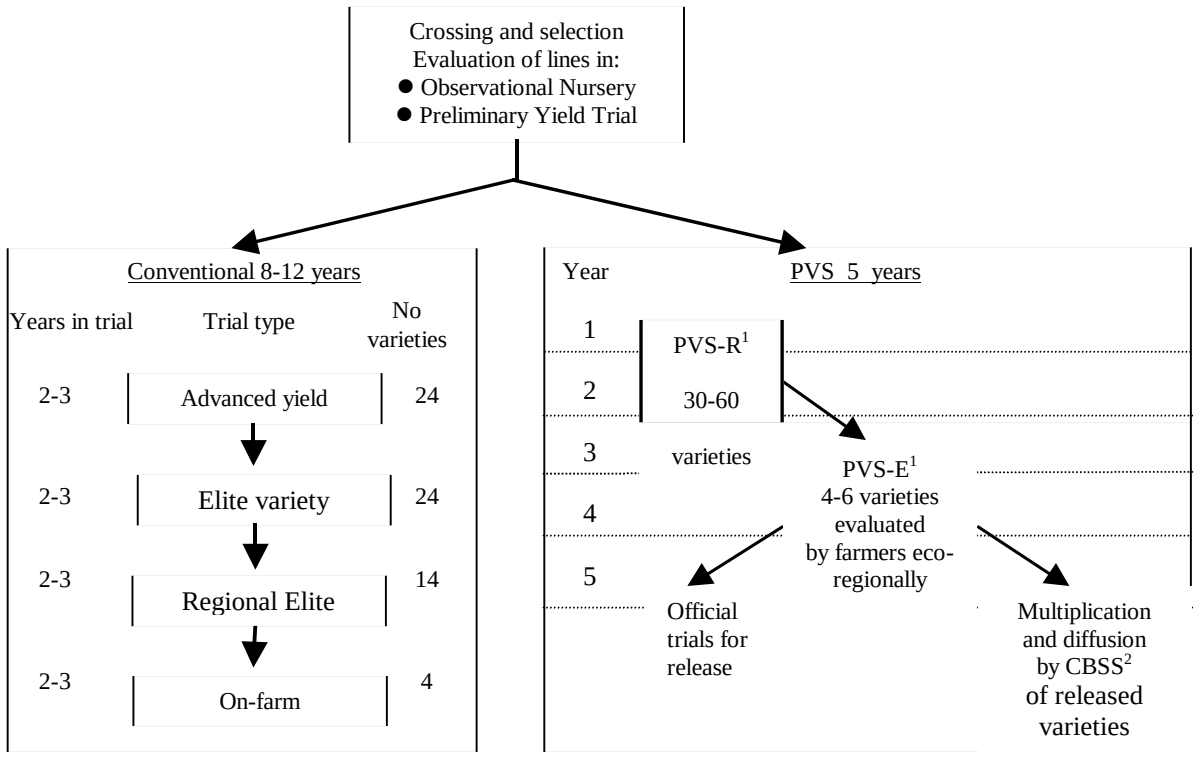
In conventional breeding schemes selection and testing procedures involve a series of multi-location trials over eight to 12 years of a diminishing number of varieties (Figure 1). This favours the selection of a few, widely adapted lines for release, often with little regard to farmer and consumer preferences or to addressing the myriad of farm level microenvironments.

At WARDA, this conventional approach to transfer of new varieties has given way to an applied and adaptive research mechanism, termed participatory varietal selection (PVS) that favours farmers playing an active role in varietal selection, development and spread (Figure 1).

The goal of PVS is to efficiently transfer improved rice varieties to farmers in order to:

- Reduce the time required to move varieties onto 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.

WARDA's approach to PVS research (PVS-R) is a three-year programme (Figure 1). In the first year, breeders identify centralised fields near villages and plant a 'rice garden' trial of up to 60 upland varieties. The varieties range from traditional and popular *O. sativas* to NERICAs, African *O. glaberrimas* and local checks. Men and women farmers are invited to visit informally the plot as often as possible but the farmers are brought as groups for formal evaluation of the varieties at three key stages: maximum tillering, maturity and post-harvest. For the first two, farmers compare agronomic traits, including weed competitiveness, growth rate, height, panicle type and growth cycle, whilst the third 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



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

Figure 1 . Diagrammatic representation of relative time scales for conventional and PVS to deliver new varieties to farmers.

and later analyzed.

In the second year, each farmer receives as many as six of the varieties he or she has selected in the first year to grow on his or her farm. Thus genetic diversity enters the communities. PVS observers, who may compromise 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 an overall 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 providing evidence of the value they place on them. Thus, in three years, 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 varieties for farmers. In the conventional scheme at least 12 years is necessary to reach this point and, even then, farmers and consumers may not appreciate the varieties selected.

A PVS extension (PVS-E) phase has recently been introduced to compliment 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 officially approved for release.

PVS activities in West Africa

PVS-R was initiated in 1966 through a small project in Boundiali in Côte d'Ivoire, where farmers

Table 1. Evolution of PVS-R activities by year in West Africa

		Number of:		
Year	**Countries with PVS-R activities**	**Countries**	**Sites**	**Farmers**
1996	Côte d'Ivoire	1	1	55
1997	Benin, Ghana, Guinea, Togo	5	17	570
1998	Burkina Faso, The Gambia, Guinea-Bissau, Nigeria, Sierra Leone	7	38	1293
1999	Cameroon, Chad, Liberia, Mali, Mauritania, Niger, Senegal	17	64	2491
2000	17 WARDA member countries	17	105	>4000

were provided with a rice garden of 57 varieties amongst which they were able to select those that met their own needs. The results were so encouraging that WARDA decided to extend the participatory approach. By 1999 all 17 WARDA member countries had instigated PVS-R at 64 sites with 2,491 farmers participating; by 2000 over 4,000 farmers at 105 sites were involved (Table 1) (WARDA 1999).

Table 2. The 58 varieties in advanced PVS testing by country in 2000

Type[1]	Variety	Benin	Burkina Faso	Cameroon	Côte d'Ivoire	Ghana	Guimea Bissau	Guinea	Mali	Mauritania	Niger	Senegal	Sierra Leone	Tchad	The Gambia	Togo	Total
S	Bouaké 189													✓			1
S	BW 293-2									✓							1
S	BW 348-1													✓			1
S	Chinese			✓													1
S	CICA 8 IR 2042-178-1									✓							1
S	FKR 21		✓														1
S	FKR 243		✓														1
S	FKR 33		✓														1
S	FKR 41		✓														1
S	IDSA 10			✓													1
S	IDSA 85	✓															1
S	IR 12979-24-1					✓											1
S	IR 28228-45-3-3-2042-178-1									✓							1
S	IR 46													✓			1
S	IR 47701-6-3-1	✓															1
S	IRAT 144												✓				1
S	IRAT 216					✓											1
S	ITA 150											✓					1
S	ITA 222													✓			1
S	ITA 398										✓						1
S	Niono 2										✓						1
S	RP 1045-25-2-1													✓			1
S	RP 17846-111													✓			1
S	SK 51-5-2										✓						1
S	Suphanbouri													✓			1
S	TGR 75															✓	1
S	TOX 3093-35-2-3-3-1															✓	1
S	TOX 3098										✓						1
S	TOX 3100										✓						1
S	WAB 181-18					✓		✓	✓								3
S	WAB 365-B-1-H1-HB														✓		1
S	WAB 50-HB								✓								1
S	WAB 515-B-16A2.2	✓											✓				2
S	WAB 515-B-16H2-2															✓	1
S	WAB 56-104											✓					1
S	WAB 56-50						✓					✓			✓		3
S	WAB 570-10-B-1A2.6	✓											✓				2
I	WAB 450-11-1-1-P31-HB						✓	✓							✓		3
I	WAB 450-11-11-P50-HB								✓								1
I	WAB 450-11-1-2-P41-HB						✓										1
I	WAB 450-24-2-3-P33-HB											✓					1
I	WAB 450-24-2-3-P38-HB							✓									1

[1]S: *O. sativa*; I: interspecific (*O. sativa* x *O. glaberrima*).

As early as 1997, significant gender differences in varietal selection were detected at Danane in Côte d'Ivoire but further analysis of the large body of data collected from other countries is needed to determine if this is common. Marked specificity in varietal selection between countries, however, was evident (Table 2), reflecting a combination of differing varietal adaptation to the wide range of on-farm (micro-) environments and diverging consumer preference. Of the 58 varieties in advanced PVS-R testing in 15 countries in 2000, 46 were selected in only one country. These accounted for 79% of the varieties, with the rest accounting for 1% or less - namely, six in two countries, five in three countries and four in one country (Table 2).

The most frequently selected varieties were derived from WARDA crosses designated by the code 'WAB', and amongst these the NERICAs were as popular as the *O. sativa* varieties. The NERICAs were particularly popular in Côte d'Ivoire, accounting for all varieties selected, and in Guinea, where NERICAS were all but one of the varieties selected. Five NERICAs have now been released in Côte d'Ivoire and two in Guinea. On average, five varieties were selected in each country, ranging from a minimum of three for Mauritania to a maximum of seven for Guinea and Tchad (Table 2).

Selection criteria applied by farmers amongst 17 countries were more consistent (Table 3). The most frequently applied criteria across countries were:

- Yield (14 countries).
- Height (13 countries).
- Short growth cycle (11 countries).
- High tillering (11 countries).
- Grain size (9 countries).
- Large grain (9 countries).

Thus across countries, heavy yielding, early varieties with profuse tillering and large grain are the most desired, but breeders must be alert to variation between countries, especially taking account of the less-frequently noted characters.

Table 3. Farmers' selection criteria applied PVS-R in 1999 in 17 countries.

Country	Selection criteria																				
	Yield	Height	Short growth cycle	High tillering	Grain size	Grain-large	Weed competitiveness	Grain colour	Grain-bold	Good response to fertilizer	Lodging resistance	Panicle size	Taste	Non-sticky grain	Drought tolerance	Medium growth cycle	Brid damage resistance	Adaptability	Emergence rate	Aroma	Disease resistance
Togo	✓								✓				✓	✓							
The Gambia	✓	✓	✓	✓		✓				✓											
Tchad	✓				✓			✓		✓			✓	✓							
Sierra Leone	✓	✓	✓		✓		✓	✓			✓						✓				
Senegal	✓	✓	✓	✓		✓															
Niger	✓	✓	✓	✓																	
Nigeria		✓			✓	✓										✓					
Mauritania		✓		✓	✓			✓							✓	✓					
Mali	✓	✓	✓	✓	✓	✓	✓			✓	✓				✓						
Liberia	✓		✓								✓										
Guinea				✓																	
Bissau	✓	✓		✓	✓	✓	✓		✓		✓				✓		✓				✓
Guinea	✓	✓	✓	✓		✓			✓			✓									
Ghana		✓		✓	✓	✓				✓											
Cote d'Ivoire	✓	✓	✓	✓	✓	✓			✓				✓	✓						✓	
Cameroon	✓	✓	✓	✓								✓									
Burkina Faso	✓	✓	✓	✓	✓			✓				✓						✓	✓		
Benin	✓		✓	✓			✓														
Total	**14**	**13**	**11**	**11**	**9**	**9**	**4**	**4**	**4**	**4**	**4**	**3**	**3**	**3**	**3**	**2**	**2**	**1**	**1**	**1**	**1**

Table 4 . PVS in Guinea: Number of farmers participating, area sown to NERICAs and estimated gain in production and income from NERICAs, 1997-2002.

Year	Number of farmers	Area (hectares) sown to NERICAs	Estimated gain in production and income
1997	116	50	
1998	380	150	
1999	1,680	250	
2000	20,000	8,000	15,000 tonnes; US$2.5 million
2002			300,000 tonnes

PVS in Guinea

PVS-R and NERICAs have made a major impact in Guinea. The first phase of PVS-R began in 1997 with support from the World Bank that enabled The Institut de Recherche Agronomique de Guinea (IRAG) and Service National de la Promotion Rurale et de la Vulgarisation (SNPRV) to collaborate with WARDA to identify varieties that could be rapidly transferred to farmers. A second phase was started in 1999.

The number of farmers participating rose from 116 in 1997 to 20,000 in 2000, with the area of NERICAs sown over this period increasing from 50 to 8,000 hectares (Table 4) (WARDA 2001). In 2000, the gain in production and in income from NERICAs is estimated at 15,000 tonnes of paddy and US$2.5 million, respectively, with additional income estimated to rise to US$300,000 in 2002 (Table 3).

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