Breeding and Dissemination Efforts of “NERICA”

(1) Breeding of Upland Rice

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Introduction

“NERICA”, which is the abbreviation of ‘New Rice for Africa’, was officially named in 2000, and now being used as a common name in many countries. Many articles regarding NERICA appeared in mass-media in Japan since that time, with expectation of another “Green Revolution”, which we observed in 1970s-’80s in Asian countries. “Miracle rice” bred by the International Rice Research Institute (IRRI) and released by many South and Southeast Asian countries, coupled with introduction of modern rice cultivation technologies such as irrigation, fertilizers, and pesticides, realized striking breakthrough in rice production. Several countries could achieve self-sufficiency of rice, and consumer price of rice decreased significantly, sweeping off the fear of dreadful shortage of rice due to rapid population increase anticipated in late 20th century.

Circumstances surrounding NERICA, however, is quite different. Asian Green Revolution was realized on the base of long traditional history and experiences of farmers and government policies towards rice. Climatic and other environmental conditions, including agricultural inputs, were fairly favorable, thus rather easy for farmers to adopt new technologies including new seeds. Information regarding newly released rice varieties, though not abundant, reached to farmers through their individual efforts (in some cases directly obtained from IRRI) and extension workers.

In case of NERICA, many difficult factors seem to be hindering from realization of Green Revolution in Africa, and some corners of international technical assistance sector seem to hesitate to offer hands of saving people from hunger and poverty. Information on NERICA varieties from the home institution as well as from testing countries is rather scarce, and not utilized commonly among different courtiers.

This series of paper will review available reports on the process of breeding, characteristics of varieties, and the situation of different countries testing varieties and breeding lines, to find ways, if any, for helping stimulate more attention to NERICA.

WARDA, with incomparable destiny in the CGIAR system

West Africa Rice Development Association (WARDA) was established in 1970 with support of UNDP, FAO, and ECA (Economic Commission for Africa), comprising 11 countries (Burkina Faso, Côte d’Ivoire, The Gambia, Ghana, Liberia, Mali, Mauritania, Niger, Senegal, Sierra Leone and Togo). The headquarters settled in Monrovia, Liberia, and main works were adaptive trials through introduction of genetic material from other regions, especially from Asia.

In 1986, WARDA became a member institution of CGIAR and intended to widen mandate. But, the next year, political instability in Liberia forced WARDA to move its headquarters to Bouaké, Côte d’Ivoire, and 6 new member countries joined including Central Africa (Benin, Cameroon, Chad, Guinea, Guinea Bissau and Nigeria).

Based on the Strategic Plan: 1990-2000, approved by TAC in March 1988, WARDA started interspecific hybridization program for breeding of upland rice in 1991, and succeeded in release of 7 NERICA varieties in 2000, which led to the CGIAR King Baudouin Award. However, WARDA had to evacuate again the research center to Bamako, Mali due to military uprising in the northern part of Côte d’Ivoire in late
2002. Two years later, seeing the peace process, the center could develop a progressive return plan to Bouaké, which was abandoned due to resurgence of the civil strife and killing of one WARDA scientist by bombing. In December, 2004, the center settled in the facilities of IITA, in Cotonou, Benin, waiting for the time of returning to Bouaké where the offices, laboratories, field facilities and the gene bank are said to remain intact (Africa Rice Center 2006).

No other international research institutions of CGIAR had such unhappy and miserable experiences, and still WARDA is striving for the welfare of African people.

**Strategy for Breeding New African Rice**

WARDA's Strategic Plan: 1990-2000 (WARDA 1988) analyzed various conditions for conducting its research during the coming decade. Rice cultivation in Africa is characterized by significant weight of upland rice, especially in West and Central Africa occupying nearly 80% of rainfed rice and 70% of farmers in the region engaged in upland rice farming, of whom 50% are women. It is a significant role for a CGIAR center to play roles for improving welfare of farmers

The consumption of rice in Africa had been increasing rapidly in parallel with urbanization in many countries, and easiness of rice both in stocking and preparing food enhanced this tendency. In order to fulfill the demand, increased rice production had to follow up, which mostly depended on expansion of cultivated land, but this would inevitably aggravate environmental conditions. Thus, new type of rice varieties was urgently needed.

Rice widely grown in Africa was japonica type of *O. sativa*, the origin of which is varieties brought from Europe in mid 16th century. The other group of rice, *O. glaberrima*, is native to Africa since 3,500 years ago, and adapted to local harsh environmental conditions, but has various agronomical defects such as easy lodging habit, easy shattering, and poor panicle characteristics. Therefore, *O. glaberrima* is now grown in very limited area. While *O. sativa* is high yielding but not adapted to various problems such as poor soil, pests and diseases, and drought, *O. glaberrima* might contribute to improve such drawbacks.

Interspecific hybridization between the two species had been tried in the past. Breeders at IRAT-ORSTOM located in Bouaké, or in Nigeria, challenged on this issue in 1970's, without success. The major problem in the hybridization breeding was high sterility and prolonged segregation, dissuading breeders from further selection (Virmani et al., 1977) However, such problems might be solved by modern biotechnology, such as embryo rescue and anther culture, which will be very effective to obtain genetically homogeneous breeding lines in a very short time.

**Breeding by Interspecific Hybridization**

Based on the WARDA Strategic Plan: 1990-2000, breeding of new type upland rice was initiated by the leadership of Dr. Monty Jones. Search for desirable parental varieties started in 1991, planting 1130 *O. glaberrima*, 275 traditional and 316 improved varieties of *O. sativa*, and eight *glaberrima* were selected to be crossed with five *O. sativa* breeding lines (selected from WARDA crosses). A total of 48 crosses were made in 1992, and succeeded in obtaining 7 crosses with more than 5% of fertile seeds in F1 generation. Pollen fertility of these F1 plants was not high, and backcrossing was conducted twice using the *O. sativa* parents as the recurrent parent. Some of the BCF1 and BC2F1 plants were submitted to anther culture. This three year project started in 1994 with the financial support by the Rockefeller Foundation. At the booting stage, young anthers were taken out of tillers, and placed onto a modified N6 growth medium containing 0.5 mg/l of Kinetin, 2 mg/l of 2, 4-D, 2% maltose, and 150 ml/l of coconut milk. Calli, produced from young anthers in 3-8 weeks on the medium, were transferred to an MS medium, and in 3-4 weeks small plantlets could be obtained. Before transferring plantlets onto the soil, these were transferred to another MS medium with half the concentration of chemicals, and MET (multi effective triazole) to get strengthened seedlings. By these procedures, haploid pollen grains develop into diploid (doubled haploid), genetically homogeneous plants, though some remain haploids, and some develop into polyploids with different number of chromosomes. Jones et al. (1997) reported that, 22% of plantlets obtained were green, and these plants could be classified into three groups depending on their chromosome number and morphological traits: 52% were haploids (12 chromosomes), 41% doubled haploids, and 7% were aneuploids/polyploids with chromosomes more than 24. This ratio of 5:4:1 was not changed by the genetic origin of the crosses. The Annual Report 1994 reported that anther culture generated 191 doubled haploid plants from genetically stable F1 and F2 populations and, in 30% of the cases, they had 92-100% fertility. By contrast, genetic
stabilization by conventional methods was impeded by sterility and led to likely elimination of desired introgressions.

The first successful group of breeding lines, which were named as NERICA number varieties in 2000, was selected from the cross WAB450. WAB denotes WARDA-ADRAO-BOUAKE; ADRAO being the French abbreviation for WARDA, and Bouaké is for the city where WARDA's upland rice breeding group located.

The cross combination of WAB450 was publicized to be WAB56-104/CG14, without any information how backcrosses were made (and not a few scientific papers and reports including several articles in the Annual Reports, the combination was erroneously described as *O. glaberrima × O. sativa*). The female parent of this cross was a breeding line obtained from the cross IDSA6/IAC164. IDSA6 is a variety bred at the Institute of Savanna (Institut des Savanes, IDESSA) of Ivory Coast, and the male parent IAC164 is a Brazilian upland rice variety.

In late August, 2006, Dr. Jones clarified, upon my inquiry of which direction the backcrosses were made, that the recurrent parent was used only as the pollen parent. Therefore, the cross combination can be shown as WAB56-104/CG14//2*WAB56-104, according to the international way of description, where //2* means that, after the initial hybridization (/), two backcrosses followed using the parent shown after the asterisk * as the pollen parent.

Interspecific hybrids of *O. glaberrima* parents, CG14, CG20, T2 and others, were studied from the viewpoint of conventional breeding. Many traits of F1 plants were similar to their glaberrima parents, such as few secondary branching of panicles, early seedling vigor. Fertility was improved to 30-65% in BC2F1. New traits such as purple pigmentation in leaf sheath, awns and apiculus appeared. In BC2F1, panicle type was much skewed towards the parental types. Some progenies combined high spikelet number of *O. sativa* with many useful traits of *O. glaberrima*, such as rapid vegetative growth, high tillering, short growth duration and good grain quality. By repeated selection, seed fertility increased up to 94-100% in BC2F1, shattering was reduced, and selection of thick culms solved the problem of lodging which was fatal to *O. glaberrima* with numerous and thin tillers.

In 1995 wet season, fixed progenies of WAB450 derived from conventional breeding and anther culture were tested in the field experiments I at WARDA’s Mbé experimental farm to study fertility, genetic stability, and agronomic traits. This trial was designed on an exhausted upland soil conditions, with two levels of input. The low input block was applied with 20 kg N/ha at 23 and 43 days after seeding, and the high input block with a total of 100 kg N/ha by three split application, and 36 kg each of P2O5 and K2O, and the field was also more carefully managed. With 4 replications, 22 newly fixed progenies (among which the present NERICA-1, -3, -4, -6 and -7 were included), 3 *O. sativa* varieties and the *O. glaberrima* parent were grown.

During the same season, experiment II was conducted in fertile upland conditions without water stress applying sprinkler irrigation, and four levels of nitrogen application (0, 40, 80 and 120 kg/ha as 2-split). All plots received 100 P2O5 kg/ha and 50 K2O kg/ha. The cultivars planted were 4 newly fixed conventionally bred lines of WAB450 combination (one of these is now named as NERICA-6), their parents CG14 and WAB56-104, with 3 replications. Three dry seeds were dibbled per hill, and then thinned to two plants per hill with a spacing of 25 × 25 cm. The parameters measured every 2 weeks were: LAI and dry weight of leaf, stem and panicle from 4 hills; specific leaf area of fully expanded blades; tiller number; plant height; and leaf chlorophyll content using SPAD, from which N content was determined; and yield components plus grain shattering based on the number of attached and missing spikelets (WARDA 1996., 1997, Jones et al., 1997).

In Experiment I, under high input block, 11 progenies (half of the tested lines) performed as the top yielders, equivalent to the *sativa* check IDSA6, with average grain yields of 3.4 to 3.8 t/ha. Under low input block, 2 progenies outyielded the *sativa* check.

In Experiment II, progenies responded strongly to N inputs in grain yields while CG14 did not at all. No lodging occurred to progenies contrasting to CG14’s 100% lodging at heading stage even in zero-N block. Progenies generally showed transgressive expression in number of primary and secondary branching, leading to higher yields. Superior initial plant growth was noted compared with *O. sativa* parent. Specific leaf area (SLA), which was related to this trait, was affected by genotypes and phenological stage, not by N resources (WARDA 1996., 1997, Jones et al., 1997).

In 2000, the first 7 varieties were named and released in Côte d’Ivoire and Guinea. These were
named as NERICA 1 through NERICA 7, and their
pedigree line No. are as follows:
NERICA1: WAB450-I-B-P-38-HB,
NERICA2: WAB450-11-1-P31-1-HB,
NERICA3: WAB450-I-B-P-28-HB,
NERICA4: WAB450-I-B-P-P91-HB,
NERICA5: WAB450-11-1-1-P31-HB,
NERICA6: WAB450-I-B-P-160-HB, and
NERICA7: WAB450-I-B-P- 20-HB.

-I-B-P is said to mean Interbreeding population
and should be spelled as IBP. HB is for Highinput
homogeneous bulk, and Ikehashi (2000) reported that
HB denotes pureline from callus of anther culture.
However, the meaning of HB is still to be confirmed,
because even before anther culture technique was
adopted, HB was used like WAB95-B-B-HB (cf. p.52,
WARDA 1994.) So far, a total of 18 upland NERICA
varieties have been named and all of them have this
HB at the end of the pedigree number. Also, it is not
yet clarified whether some of these were selected
through anther culture. Rather, it is said that none of
these were bred through anther culture, on the basis
that -A-, which indicates anther culture, is not shown
in the pedigree names.

Selected References

Africa Rice Center 2006. WARDA: A Concise History.
http://www.warda.org/warda/history.asp.
Ikehashi, Hiroshi 2000. Systemwide Review of Plant Breeding
Jones, Monty P., Michael Dingkuhn, Gabriel K. Aluko and Mandé
Semon 1997. Interspecific *Oryza sativa* L. × *O. glaberrima*
Steud. progenies in upland rice improvement. Euphytica 92:
237-246.
improvement in Tropical Anglophone Africa. In: I. W.