Strategy for hybrid rice breeding in Brazil using recurrent selection

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The People's Republic of China is still the only country cultivating hybrid rice because, until now, the seed production system has depended entirely on agronomic practices that assist pollination. These practices must be performed manually; for example, the flag leaf must be cut and the panicles agitated with a string during the flowering stage. As they cannot be easily applied in other countries such as Brazil, an alternative technology must be developed.

CNPAF (National Research Centre for Rice and Beans) and IRAT (Institute for Research in Tropical Agriculture and Food Crops) have already begun work in the creation of hybrid parental lines: the female will possess long stigmas to assure an increase in the outcrossing rate and to permit hybrid seed production at a lower cost. In the long term, the creation of these female lines will be greatly facilitated by the use of recurrent selection.

Recurrent selection methods are widely used in cultivated crops and their efficiency has been fully demonstrated. The obtention of genetic male sterility in rice has rendered its application easy nowadays (Fujimaki, 1978). Recurrent selection has already been used in CNPAF for pure line breeding and will be applied in hybrid rice breeding.

This article aims to describe a strategy for hybrid rice breeding using recurrent selection.

JUSTIFICATION OF A BREEDING STRATEGY IN RICE USING RECURRENT SELECTION

The production of pure lines or hybrids in most of the world's traditional rice breeding programmes is based on the use of pedigree or bulk selection. The disadvantages of these methods are the restricted recombinations between loci, the loss of variability during inbreeding because of the high-intensity selection used and the length of each selection cycle. In the short term this method has proved to be relatively efficient. However, the best long-term use of variability can be obtained through the application of recurrent selection, which has been created to resolve these problems.

Recurrent selection will improve the mean of a population through repeating cycles of intercrossing followed by selection (Fig. 1). This method stimulates the recombinations between loci and, by the selection of favourable genes at each cycle, their frequency in the population will increase.

At the country and generation levels, a traditional breeding programme can be compared to a very slow recurrent selection scheme. In barley, for example, the time required for selection, testing and reincorporation of improved genetic recombinants into the breeding programme ranges from 6.5 to 10.5 years, whereas the length of a recurrent selection cycle is from six months to two years (McProud, 1979).

To preserve the variability, the breeder has to use a low-intensity selection; therefore, the short-term progress will not be as impressive as that of the pedigree method. For these reasons, Gallais (1977, 1989) proposed to compromise between the short term and the long term, separating variety creation from population improvement in an integrated strategy of selection (Fig. 2). Its main axis is recurrent selection. At each cycle new cultivars can be incorporated into the programme and new varieties can be released by, for example, pedigree selection. This strategy has already been applied in rice by CNPAF/IRAT to produce pure lines and has been initiated to produce hybrids in a form compatible with economical seed production.

All CNPAF/IRAT populations use the monogenic recessive male-sterility gene obtained from a mutant of IR36 (Singh and Ikehashi, 1981) to facilitate intercrossing. This gene has been incorporated into the parental lines of the population through backcrossing. The intercrossing is achieved by harvesting the male-sterile plants (Fig. 1).

Two populations form the first selection cycle in CNPAF for pure line breeding: an upland japonica population, CNA-IRAT 5 (Taillebois and Guimarâes, 1989), which has been selected on a multitrait linear index in S_2 families, and an indica one, CNA-IRAT 4

TABLE 1 **Recurrent selection populations being formed or in use by CNPAF, IRAT, IDESSA, CFR and FOFIFA**

Institutions	Population composition	Objectives	Phase
CNPAF/IRAT	Indica maintainer to "WA" CMS with introgression of *Oryza longistaminata* A. Chev.	Hybrid rice breeding female population	Being formed
CNPAF/IRAT	Indica restorer to "WA" CMS	Hybrid rice breeding male population	Being formed
CNPAF/IRAT	CNA-IRAT 3-population introgressed by *Oryza longistaminata* A. Chev.	Allogamy transfer	In use
CNPAF/IRAT	CNA-IRAT 4-indica rice	Multicharacter improvement	In use
CNPAF/IRAT	CNA-IRAT 5-japonica upland rice	Multicharacter improvement	In use
CNPAF/IDESSA/ IRAT	CNA-IRAT 5-japonica upland rice	Horizontal resistance to *Pyricularia oryzae*	Being formed
FOFIFA/IRAT	Japonica irrigated rice	Adaptation to highlands	Being formed
FOFIFA/IRAT	Japonica upland rice	Adaptation to highlands	Being formed
CFR/IRAT	Japonica irrigated rice	Adaptation to temperate regions (Europe)	Being formed

CFR-Centre Français du Riz, Arles, France.
CNPAF-National Research Centre for Rice and Beans, Goiânia, Goiás, Brazil.
FOFIFA-Foibe Fikaromana Fambolena, Antananarivo, Madagascar.
IDESSA-Institut des Savanes, Bouake, Côte d'Ivoire.
IRAT- Institute of Research in Tropical Agriculture and Food Crops, Lomé, Togo.

(Taillebois and Neves, 1989). At each cycle, varieties are created by pedigree selection from the best S_2 families. Other populations are being formed (Table 1).

APPLICATION OF RECURRENT SELECTION FOR HYBRID RICE BREEDING

The production of hybrid seeds involves a cytoplasmic-genetic male-sterility (CMS) source (Fig. 3). The most common for rice is the wild abortive (WA) pollen system and it is widely used. The restoration is oligogenic (Govinda Raj and Virmani, 1988).

The current limitation on hybrid seed production is the low rate of cross-pollination, which increases the cost of the production, even making it prohibitively expensive. Taillebois (1983) first proposed the development of female lines adapted to cross-pollination by transferring the long-stigma trait from *Oryza longistaminata* A. Chev., an African allogamous wild rice, to *O. sativa* L. In addition, Taillebois and Guimarâes (1987) described a recurrent selection scheme for allogamy that would facilitate the transfer and the selection for this trait.

Further studies led to the conclusion that it was possible to develop a reciprocal recurrent selection, like the one first used by Comstock, Robinson and Harvey (1949) or Gilmore (1969) and Dogget (1972) with a male-sterility gene.

The female population will be composed of maintainer plants with long stigmas and improved to increase both its cross-pollination rate and its combining ability for yield with the male population. The male population will be composed of restorer plants and improved to increase its restoration rate and its combining ability for yield with the female population.

The creation of parental lines A/B and R at each cycle of the recurrent selection will be greatly facilitated and the variability efficiently used by the application of this integrated strategy.

STRATEGY FOR HYBRID RICE BREEDING AT CNPAF

The upland hybrid rice programme has been terminated in CNPAF for various reasons. Only the indica hybrid rice strategy will be described here.

Hybrid rice breeding in the short term

The development of A/B and R lines at CNPAF has been affected by the identification of maintainers and restorer plants among existing Brazilian cultivars or fixed lines proceeding from the traditional breeding programme.

All available pure lines are crossed with a restoration tester carrying WA male sterility cytoplasm. Maintainers and restorers are identified on F_1 fertility rate. The A/B lines are produced introducing the long-stigma trait by backcrossing and the WA male sterility cytoplasm in the maintainer plants.

The best combinations are selected between the R and A lines for commercial traits and the hybrids are compared with the best improved cultivars.

Hybrid rice breeding in the long term

In the long term, CNPAF and IRAT will apply the strategy, using recurrent selection already described, as follows:

Constitution of the female and male populations. CNPAF and IRAT have begun developing a female and a male population from the CNA-IRAT 4 population. Its average outcrossing rate on male-sterile plants is 34 percent after four intercrossing cycles. Observations show that selection for this trait is possible. Fertile plants of this population were crossed with a WA-CMS tester. The fertility restoration rates were observed in the F_1 generation and the maintainer or restorer sources identified. The progenies of each type were saved and mixed to form a new population. To broaden the genetic basis of the female and male populations, a collection of maintainer and restorer lines are being introduced this year.

The long-stigma trait will be transferred using the maintainer plants of CNA-IRAT 3 population. It is composed of three *O. sativa* L. cultivars (IRAT 10, IR36 and V41 B) and *O. longistaminata* A. Chev., whose introgression in the population permitted an increase of 41 percent in the average outcrossing rate after four intercrossing cycles.

Description of the reciprocal recurrent selection scheme. The aim of this half-sib family reciprocal recurrent selection (HS-RRS) scheme is to improve the yield combining ability for the reciprocal population of both female and male populations. Moreover, as the allogamy characters will be specifically improved in the maintainer population, the restoration rates of the restorer population will be tested and selected.

Progenies of the male-sterile plants of each population will be chosen based on the outcrossing rate data (Fig. 4). The best half-sib family fertile plants will be harvested, some of the seeds saved and the rest sowed in an intercrossing field system with the reciprocal population. The S_1 fertile plants will be eliminated and the half-sib families tested for yield in two locations. The best 20 to 30 S_1 families will be intercrossed to form the next population.

To improve the intrinsic value of each population, an S_2 progenies test can be realized.

Four generations (two years) are necessary to complete one cycle of recurrent selection. Combining ability and restoration tests are done during the normal cropping season.

At each intercrossing generation, the variability will be broadened by incorporating maintainer or restorer lines.

Hybrid parental lines will be created at each cycle by pedigree selection on the *per se* value. The long-stigma trait will be selected in early generations (S_2 or S_3). The restoration ability will be tested on inbred lines and the maintainer plants sterilized by WA cytoplasm. The specific combining ability will be tested.

For upland hybrid rice breeding, the same strategy can be applied. In this case, the recurrent selection is even more interesting, considering the lower rate of intercrossing in CNA-IRAT 5 (10 percent after four intercrossing cycles), which will be used as the basic population. The "BT" cytoplasmic-genetic sterility system has been chosen.

CONCLUSION

Reciprocal recurrent selection will allow for the improvement of the male and female populations in the long term, and it will enhance combining ability, allogamy and restoration rates. This will facilitate the economical production of hybrid seeds while the variability will be more efficiently used. This strategy is being applied in Brazil by CNPAF and IRAT.

An improvement in the yield levels obtained with high-yielding rice varieties is sought by pursuing alternate strategies of recurrent selection and development of hybrids.

Choosing between pure line breeding and hybrid breeding depends basically on the genetic variability of the material (Gallais, 1988); however, technical, economic and sociological factors will be decisive in the final analysis.

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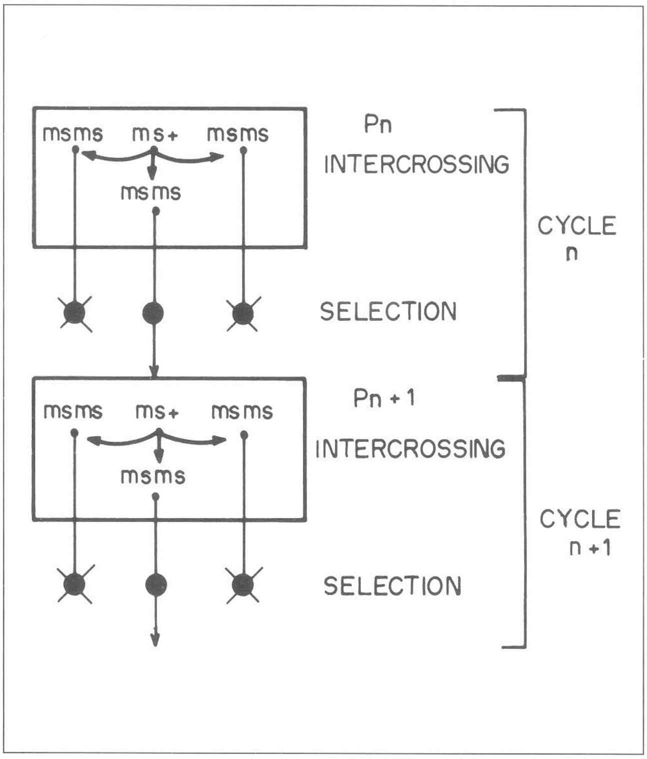
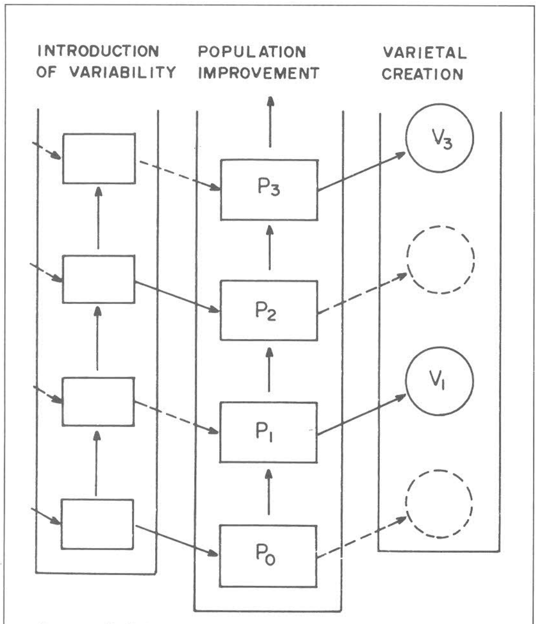
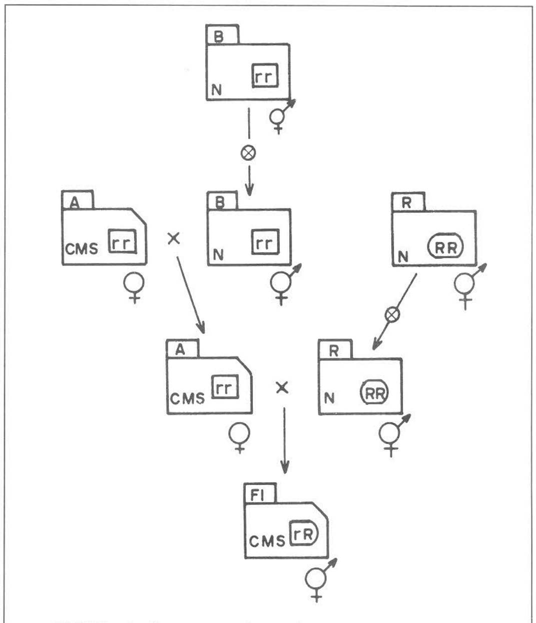


FIGURE 1
Principle of recurrent selection using a recessive male-sterility gene



Source: Gallais, 1989

FIGURE 2
Strategy of selection and varietal creation



CMS/N: sterile or normal cytoplasm
R/r: genes of fertility restoration

FIGURE 3
Principle of hybrid rice production using male-sterility cytoplasmic gene

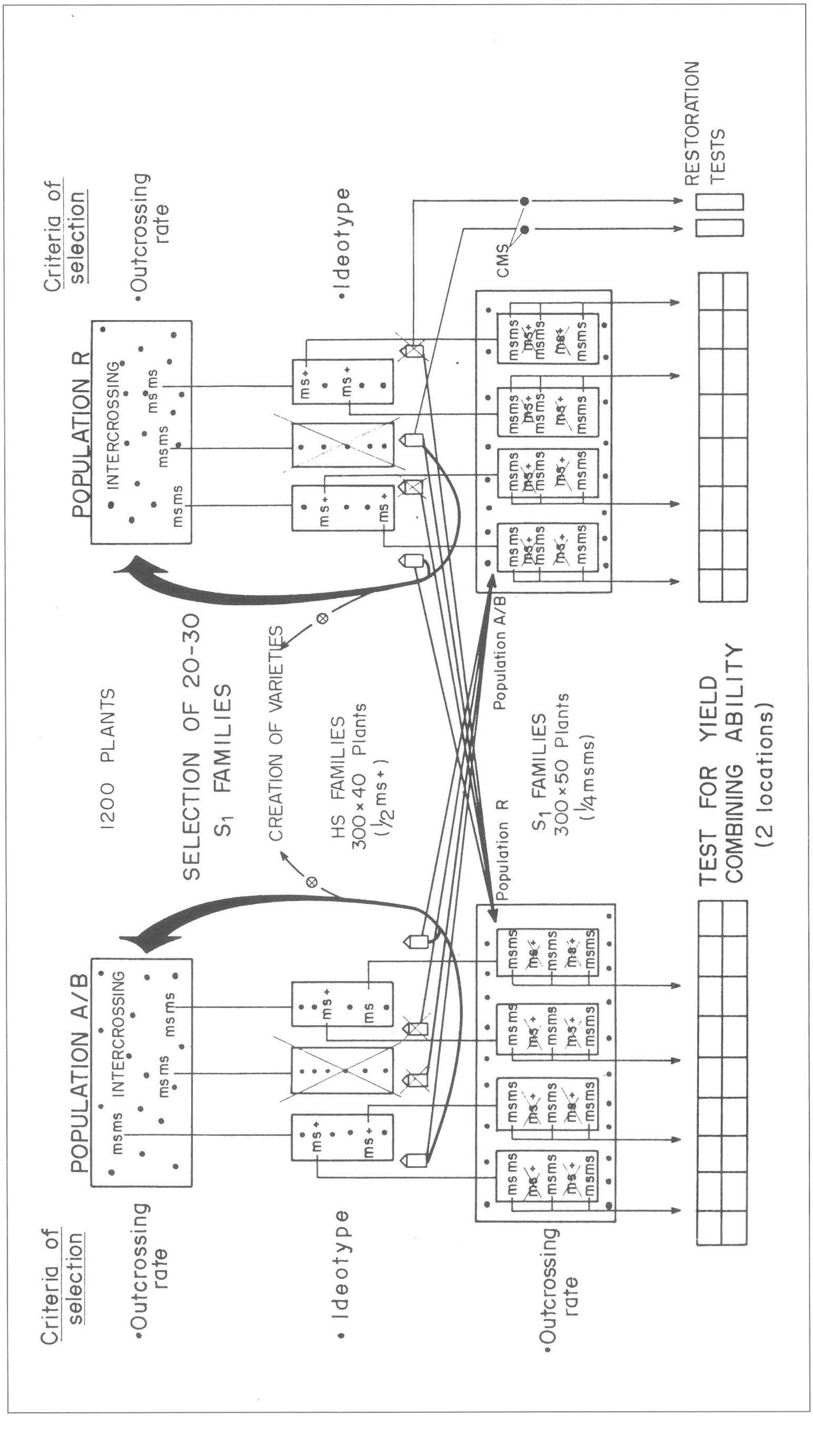


FIGURE 4
Half-sib direct reciprocal recurrent selection for yield, restoration and allogamy using recessive male-sterility gene