Euphytica
DOI 10.1007/s10681-008-9819-x

Improvement of cropping systems by integration of rice breeding: a novel genetic improvement strategy

Michel Vales · Lucien Séguy · Serge Bouzinac · James Taillebois

Received: 2 July 2007 / Accepted: 11 September 2008

Abstract Rice improvement is based to an increasing extent on ever-sharper genetic analysis to the detriment of classical breeding, which is disappearing. Analytical genetics are very promising, but they cannot replace integrated and finalized breeding. Little attention has been paid to improving participatory rice breeding methods for subsequent integration into sustainable cropping systems. Special methodological initiatives are required to ensure the success of this breeding-agronomy integration. This integration of inexpensive breeding methods has increased the biodiversity of rice: low temperature and drought tolerant upland rice varieties for mountain areas, and polyvalent varieties, which have the ability to grow in both rainfed or irrigated conditions, they are perfectly adapted to improved cropping systems and to beneficiaries' needs and preferences. These preliminary results on this integration demonstrate that the present approach is relevant.

M. Vales (✉)
UMR Biology and Genetics of Plant-Pathogen Interactions for Integrated Protection, CIRAD/INRA/SupAgro, Campus International de Baillarguet, TA, A-54/K, 34398 Montpellier Cedex 5, France
e-mail: michel.vales@cirad.fr

L. Séguy · S. Bouzinac
UPR Direct Seeding and Cover Crops, CIRAD, 34398 Montpellier Cedex 5, France

J. Taillebois
UPR Rice Breeding and Management, CIRAD, 34398 Montpellier Cedex 5, France

Keywords Agronomy · Breeding · Integration · Participatory selection · Recurrent selection · Rice

Introduction

Rice improvement is based to an increasing extent, on ever-sharper genetic analysis (see bottom of Fig. 1; Sasaki 2006) to the detriment of classical breeding, which is disappearing (Knight 2003). Little attention has been paid to improving rice breeding methods for subsequent integration into cropping systems. Our complementary methodological approach is also holistic (see top of Fig. 1) and takes genetic, agroecological, and socioeconomic diversity into full consideration (CIRAD 2006).

Methods

The genetic diversity available in large working rice germplasm collections should be tapped by creating and utilizing maximal polymorphism through a high number of crosses and genetic recombinations (Fig. 2). Consequently, F2 populations (two progenitors) were discarded in favor of recurrent populations (broad sets of progenitors) (Fujimaki 1979).

Breeding methods have to be simplified and optimized in order to decrease the cost of obtaining new varieties (Fig. 2). We have thus developed improved methods involving plant–parasite reciprocal recurrent selection (Vales et al. 2000) and narrow-based recurrent populations (NBP), which involve only four or five progenitors that were independently the very best for one of the main target traits (Vales et al. 1998). NBP use facilitated and lowered the cost of marker assisted recurrent selection (Fig. 1) and participatory recurrent selection (Vales et al. 2002).

Beneficiaries' needs were taken into consideration through their early participation in the rice breeding process (Figs. 2, 3). This first involved their participation in recurrent population improvement (Vales et al. 2002; Trouche 2005).

We have diversified the evaluation conditions to consider genotype-environment interactions (Fig. 2). The final multilocation evaluations were replaced by direct integration of the whole breeding process into sustainable cropping systems (Fig. 3; Vales 1989). This integration was the result of the concomitant improvement of rice breeding and direct seeding mulch-based cropping systems and conservation agriculture (DMC) (Raunet and Naudin 2007) through the same holistic approach.

This integration of breeding into sustainable cropping systems enhances the hierarchical classification of targeted traits. For example, in rice DMCs, blast has very little impact (Ratnadass et al. 2006), so only a moderate level of partial resistance was required, and the focus was more on increasing physiological yields.

Results and conclusion

The integration of participatory breeding into DMCs, involving inexpensive breeding methods, could enhance the biodiversity of the improved varieties. This has resulted in breeding of low temperature and drought tolerant upland rice varieties for mountain

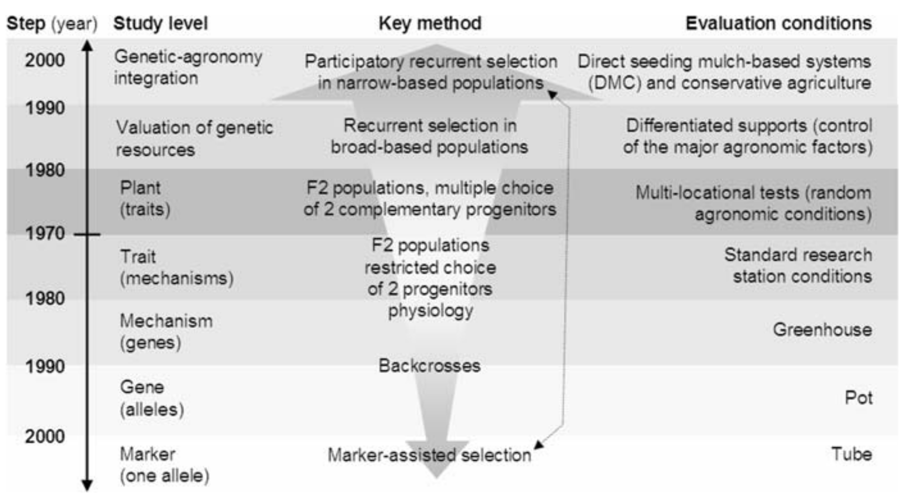


Fig. 1 Disruptive evolution of rice genetic improvement—analytical and integrative approaches

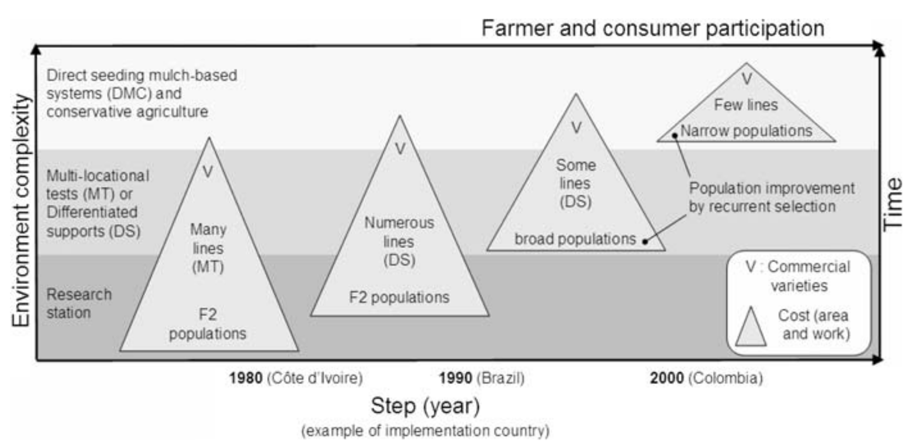
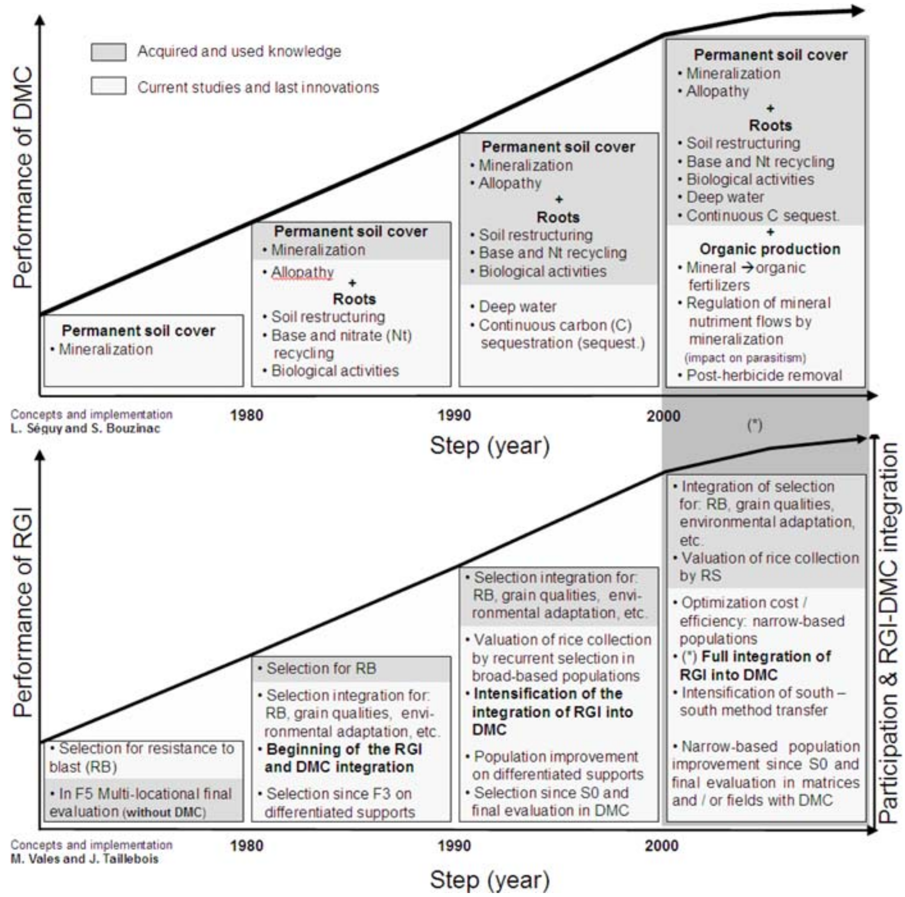


Fig. 2 Steps in the integration of rice breeding into direct seeding mulch-based systems (DMC) and conservation agriculture

Fig. 3 Concomitant performance progress of direct seeding mulch-based cropping systems (DMC) and conservation agriculture, and of rice genetic improvement (RGI) via its integration into DMCs



areas (Vales and Razafindrakoto 1996; Vales et al. 2003), and polyvalent varieties, which have the ability to grow in both rainfed or irrigated conditions, perfectly adapted to DMC and to beneficiaries' needs and preferences (Charpentier et al. 2005; Séguy et al. 2006; DANAC 2006; Vales et al. 2006).

Analytical genetics are very promising, but cannot replace integrated and finalized breeding. Special methodological initiatives are required to ensure the success of this breeding-agronomy integration. Preliminary results on this integration demonstrate that the present approach is relevant.

References

Charpentier H, Husson O, Andriantsilavo M et al (2005) New rice varieties and cropping systems for paddy fields with poor water control in Madagascar. In: Third world congress on conservation agriculture, Nairobi, Kenya, pp 22–27. http://agroecologie.cirad.fr/pdf/Poster_SEBOTA_%20Nairobi2005.pdf. Retrieved 15 Jan 2007

CIRAD (2006) Agroecology network. http://agroecologie.cirad.fr/. Retrieved 30 Aug 2008

DANAC (2006) Agreement Danac and El Aceituno outputs. In: La semana, number 510. http://www.danac.org.ve/semana/index.php?id_semana=450. Retrieved 30 Aug 2008 (in Spanish)

Fujimaki H (1979) Recurrent selection by using genetic male sterility for rice improvement. JARQ (Tsukuba) 13(3):153–156

Knight J (2003) A dying breed. Nature 421:568–570

Ratnadass A, Michellon R, Randriamanantsoa R, Séguy L (2006) Effects of soil and plant management on crop pests and diseases. In: Uphoff N, Ball AS, Fernandes E, Herren H, Husson O, Laing M, Palm C, Pretty J, Sanchez P (eds) Biological approaches to sustainable soil systems. CRC, Boca Raton, pp 589–602

Raunet M, Naudin K (2007) Combating desertification through direct seeding mulch-based cropping systems (DMC). Les dossiers thématiques du CSFD. N°4. CSFD, Montpellier, France. 40 pp. http://www.agropolis.fr/pdf/CSFD/CSFD_dossier_4_eng.pdf. Retrieved 30 Aug 2008

Sasaki T (2006) The complete rice genome sequence as a gold standard for cereal genomics. In: Second international rice congress. New Delhi, India, p 1

Séguy L, Bouzinac S et al (2006) Annual report for 2005. 159 pp. http://agroecologie.cirad.fr/pdf/1133391616.pdf. Retrieved 30 Aug 2008 (in French)

Trouche G (2005) Participatory rice breeding, using population improvement: a new methodology adapted to the needs of small farmers in Central America and the Caribbean. In: Guimarães EP (ed) Population improvement: a way of exploiting the rice genetic resources of Latin America. FAO, Rome, pp 995–1006

Vales M (1989) Strategy for the improvement of the resistance to rice blast disease. In: International symposium on the role of the biology to resolve the food crisis in Africa. African network of biosciences, Yamoussoukro, Côte d'Ivoire, 12 pp (in French)

Vales M, Razafindrakoto J (1996) Nepalese earliness for Malagasy rice of altitude. In: International workshop on research and development of the rice of altitude. FOFIFA-CIRAD. Antananarivo, Antsirabe, Madagascar, 7 pp (in French)

Vales M, Chatel MH, Borrero J et al (1998) Recurrent selection for rice (*Oryza sativa*) blast (*Magnaporthe grisea*) resistance in population with narrow genetic base. In: Proceedings of the international symposium on rice germplasm evaluation, and enhancement. August 30 – September 2, 1998, Stuttgart, Arkansas, USA. Rutger JN, Robinson JF and Dilday RH (eds) Arkansas Agricultural Experimental Station, Division of Agriculture, University of Arkansas, November 1999 Special Report 195, p 141. http://www.arkansasagnews.uark.edu/195.pdf. Retrieved 22 Sept 2008

Vales M, Tulade E, Dossmann J et al (2000) Recurrent selection to improve partial and complete resistance and other agronomic traits in population PCT-6. In: CIAT project IP4––improved rice germplasm for Latin America and the Caribbean—Annual Report 2000, pp 78–80. http://www.ciat.cgiar.org/riceweb/pdfs/report_2000/output_2.pdf. Retrieved 22 Sept 2008

Vales M, Dossmann J, Salazar S, García J et al (2002) Recurrent selection and participatory breeding for upland rice with cold tolerance for small holders of the Colombian Cordilleras. In: Proceeding of second international workshop on upland rice. CIAT Santa Cruz, Bolivia. CIAT, Santa Cruz (in Spanish)

Vales M, Dossmann J, Salazar S et al (2003) RHICO: a new rice type for confronting food insecurity in the mountains and a new option for template upland rice—from participatory recurrent selection to marketing. In: Third international template rice conference. Punta del Este, Uruguay, 13 pp. http://www.fao.org/ag/agp/AGPC/doc/services/pbn/pbn-140.htm. Retrieved 30 Aug 2008

Vales M, Séguy L, Dossmann J et al (2006) CIRAD Rice research highlight. Release in Colombia of the rice variety ACD 25-28 in direct sowing mulch bases cropping systems: 85–87 (in English). In: Séguy L, Bouzinac S et al (eds) Rapport annuel d'activités 2006—UR1/CIRAD-CA—Brésil, 162 pp. http://agroecologie.cirad.fr/pdf/1166258880.pdf. Retrieved 30 Aug 2008 (in French)