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Comparing decentralized participatory breeding with on-station conventional sorghum breeding in Nicaragua: II. Farmer acceptance and index of global value

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ABSTRACT

Participation of farmers in the genetic improvement of staple crops in vulnerable environments is now widely accepted as a necessary approach for enhancing the acceptance of improved varieties. Our study set out to assess the genetic gains achieved by collaborative decentralized participatory breeding programmes in comparison with those obtained by conventional breeding. The gains were estimated on farmer acceptance and combination of agronomic and quality-related traits, from three breeding programmes on *tortillero* sorghum for low-input cropping systems in northern Nicaragua. In each programme, three selection modes were compared: selection by the farmers on-farm (FoF), by the breeder on-station (BoS), and by the breeder on-farm (BoF). Our results showed that the lines produced by FoF selection were more praised by the farming community, compared to BoS and BoF selection. Comparative advantage of FoF selection was to develop higher proportion of lines with an adequate balance between agronomic traits, and with better quality traits related to grain appearance and plant type. A composite selection index, ISFA, was computed for each line as a combination of agronomic performance in the target environment, and *ex post* farmer appraisal. Based on this index, FoF selection proved again to be more efficient than BoS and BoF selection. We propose that such a selection index be used in participatory breeding programmes to improve their efficiency.

1. Introduction

For low-input agriculture in vulnerable environments whose products are generally earmarked for family consumption, the success of a new variety depends on its agronomic performance in the existing cropping systems and a combination of traits related to plant type and product quality. Farmer preferences for specific plant types, e.g. associated with adaptation to certain cropping systems or local environmental constraints, vary depending on the local production systems. Likewise, if grains or tubers are concerned, quality is a multi-component trait, including appearance (colour, shape and size), conservation and processability, and the culinary value for various local dishes. These components are often influenced by local features. This makes farmer preferences for these quality traits and, even more so for trait combinations, difficult to assess and to integrate in a formal breeding programme. Thus, under these conditions, intense participation of farmers in the selection process is now widely considered as essential for developing appropriate varieties (Morris and Bellon, 2004; Witcombe et al., 2005; Ceccarelli and Grando, 2007).

In this respect, decentralized participatory variety selection (PVS) has proved to be highly effective for providing enhanced varieties which combine superior agronomic performance and adequate quality traits, in a shorter time and at low cost (Joshi and Witcombe, 1996; Tiwari et al., 2009; Trouche et al., 2009). However, few studies have measured the real effectiveness of decentralized breeding programmes managed by farmers from early selection generations, compared with centralized conventional breeding. In a review of twelve participatory plant breeding (PPB) programmes, Witcombe et al. (2006) concluded that collaboration with farmers at the selection stage globally showed favourable results. In comparison with formal programmes managed on-station by professional breeders, the PPB programmes seldom produced genotypes with significant higher yield, but more often with an improved balance between earliness and yield, or between yield and grain quality.

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In general, a major key to the success of a plant breeding work lies in a combination of relevant quantitative traits such as yield, cycle duration, disease and pest resistance, which contribute to agronomic performance, and farmers' criteria regarding specific quality traits, which guarantee ultimate acceptance of the variety. This issue may be addressed through the elaboration of a selection index, attributing appropriate weights to the various key traits. Such an approach has been more extensively explored for animal breeding than for plant breeding. It was first proposed by Smith (1936) and then generalized in plant breeding programmes from the eighties onwards, especially for perennial plant improvement. Selection indices are often used in single trait selection, integrating data from related traits to increase selection effectiveness for the target trait. However, when selecting for multiple traits, significant difficulties arise in assigning economic weights to the various traits (Sölkner et al., 2008). In a comparative review of selection for multiple traits in plant and animal breeding, Sölkner et al. (2008) observed that plant breeders often use non-formalized ways of combining selection pressure on various traits. For these authors, this is because it is generally difficult to estimate the economic value of each trait, as well as the genetic variances and co-variances of the traits considered. Nevertheless, empirical weighting, if judiciously applied, has also proved to be effective for meeting the selection objectives. In one of the few papers linking a selection index and farmer preferences, Sharma and Duveiller (2006) reported that a selection index, when applied in a wheat breeding programme managed on-station, based on resistance to a major disease, early maturing and high kernel weight, could simultaneously improve yields and farmer acceptance under on-farm conditions.

Beginning in 2003, several participatory sorghum breeding programmes were initiated in Nicaragua under a CIRAD-CIAT project managed in collaboration with Nicaraguan partners (Trouche et al., 2009). They set out to develop more suitable sorghum varieties for the low-input farming systems of the Northern Region, which is characterised by a semi-arid climate with highly variable rainfall, and poor soil fertility (Trouche et al., 2011). This research was conducted between professional breeders, agronomists and local farmer groups. Three of the breeding schemes were designed and implemented simultaneously by way of three selection modes: selection by a professional breeder on-station (BoS), by a professional breeder on-farm (BoF) and by farmer–breeders on-farm (FoF). In a previous paper, the agronomic performance of lines derived from these three selection modes was compared and discussed (Trouche et al., 2011). This paper first looks at *ex post* acceptance by farmers of the lines developed from each selection mode with two central questions: (i) are the lines created by FoF selection also those that are preferred by a larger community of farmers in the same region? and (ii) which agronomic and quality traits might help to explain these possible preferences? It then proposes the use of a composite selection index, combining agronomic performance and farmer acceptance, for defining the global value of the lines derived from each selection mode, and finally discusses the advantages of such an index.

2. Materials and methods

This study considered three breeding schemes implemented to improve white-grain, non photoperiodic *tortillero* sorghum, each developed from a distinct segregating population, called PCR-1, PCR-2 and CIR-6. For simplicity, the three breeding schemes will be identified hereafter by their respective population names. Each of them was implemented by way of the three selection modes, FoF, BoS and BoF, as described above.

2.1. Partners

The participants in the sorghum breeding programmes included a professional sorghum breeder from CIRAD, two agronomists from the Cipres NGO, and three farmer–breeder groups, members of local farmer organizations, who had also participated in the PVS phase of the research project.

2.2. Breeding objectives

An iterative interaction process between the local farmer groups and the research team led to the identification of breeding goals and a ranking of the selection criteria, as described in a previous publication (Trouche et al., 2009). At each on-farm site, selection criteria were refined through discussions between the local farmer–breeders and the research team. For the breeding schemes involving the PCR-1 and PCR-2 populations, the selection criteria were detailed in a previous paper (Trouche et al., 2011). Table 1 summarizes the breeding goals defined for the target ecosystems, the sites of selection and the main selection criteria of the three breeding schemes considered in this study.

2.3. Description of the breeding schemes

A complete description of the two breeding schemes developed from the PCR-1 and PCR-2 populations was given by Trouche et al. (2011). The third breeding scheme, identified as CIR-6, was developed from a single cross made between a well-adapted local cultivar, Sorgo Ligero, and an improved inbred line developed in Burkina Faso, BF 94-6/11-1K-1K, selected for giving short plant type and enhanced fodder quality, as well as midge resistance (Dakouo et al., 2005). Table 2 summarizes the history and the general design of all three breeding scheme studied. In each scheme, the same quantity of seed and similar plot area were used both on-station and on-farm. At the on-farm selection sites, three to four farmers, previously involved in the PVS phase of the project, were invited to participate in the breeding programme. In Totogalpa, the selection activities of the CIR-6 and PCR-1 schemes were managed in two districts of the village with two distinct farmer groups. Before

Table 1
Breeding goals, target ecosystems, sites of selection and main selection criteria of the three breeding schemes considered in this study.

Breeding goal and target ecosystem	Schemes	Sites of selection	Selection criteria of higher priority
Grain production under low inputs cropping systems in dry areas	CIR-6 and PCR-1	CNIA station + Totogalpa	Early cycle (90 days to maturity) with drought tolerance Adaptation to low soil fertility Grain yield up to 2 t ha^{-1} Grain quality for auto-consumption (Tortillas and others)
Grain + fodder under intermediate intensification in more favourable areas	PCR-2	CNIA station + Pueblo Nuevo	Intermediate cycle (100–110 days to maturity) Good response to semi-intensified cropping systems Plant height = 1.5–1.8 m High fodder production with improved quality (high leaf/stem ratio) Grain yield up to 3 t ha^{-1} Grain quality for auto-consumption and sale