



Pre-Breeding: A Review

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Abstract

Pre-breeding is the most promising alternative to link genetic resources and breeding programs. Pre-breeding refers to all activities designed to identify desirable characteristics and/or genes from unadopted (exotic or semi-exotic) materials, including those that, although adapted have been subjected to any kind of selection for improvement. As pre-breeding is being carried out, the resulting materials are expected to have merit to be included in ordinary breeding programs.

Although there are some different concepts of exotics, Hallauer & Miranda Filho (1988) consider that exotics for pre-breeding purposes include any germplasm that does not have immediate usefulness without selection for adaptation for a given area. In this sense, exotic germplasms are represented by races, populations, inbred lines, etc. Consequently, the results of crosses between adapted and exotic materials, where different proportions of introgression are obtained and evaluated, have been denominated as semi-exotic materials. According to Hallauer (1978), the utilization of semi-exotic populations has been the most common procedure to evaluate exotic germplasms. To obtain promising results with exotics their reproduction is necessary for a few generations in order to allow genetic recombination accompanied by mild selection. Before useful recombinants can be selected a minimum of five generations of random mating with mild selection pressure is indicated (Lonnquist, 1974).

KEY WORDS: - domesticated, semi-exotic, mild selection,

IMPORTANCE

Pre-breeding programs can generate new base populations for breeding programs and also assist in identifying heterotic patterns for hybrid programs. Marshall (1989) considered that the lack of pre-breeding programs is the most limiting factor for using landrace germplasms and unadapted exotic lines from collections. Pre-breeding at CIMMYT's Germplasm Bank collections, aims to provide to breeder's ready utilization of materials with specific traits of interest as well as a means to broaden the diversity of improved germplasm. Caribbean collections are receiving first priority for pre-breeding efforts, based on the interest of this germplasm both by tropical and temperate maize breeders, and the fact that, evaluations of these collections are already under way (Taba, 1994). As a result of these pre-breeding programs, many gene pools and populations were developed by CIMMYT for tropical lowlands.

Clearly pre-breeding programs are time-consuming and tiresome. For private plant breeders, generally under pressure to fulfill short term goals, exotics that underwent pre-breeding are likely to be more useful and certainly more attractive (Smith & Duvick, 1989). Consequently, close cooperation between public and private institutions can be especially helpful in pre-breeding programs (Smith & Duvick, 1989; Nass et al., 1993).

Heterotic pattern is a key factor for utilizing germplasm to maximize performance of the population-crosses and derived hybrids (Eberhart et al., 1995). Pre-breeding can identify heterotic patterns for breeding programs where the goal is hybrid development. Although the heterotic pattern between Lancaster Sure Crop and Reid Yellow Dent has received greatest use in U.S. programs, other heterotic patterns have been considered as Leaming and Midland (Hallauer et al., 1988). Identification of other heterotic patterns should contribute for a broadening of germplasms to be used commercially (MGenerally, hybrid programs showed good results in tropical areas, especially where the existence of well-structured and competitive private companies further contributed to this performance. In Brazil, flint by dent crosses is widely used and usually include materials derived from either Cateto by Tuxpeño or Suwan-1 by Tuxpeño (Hallauer et al., 1988). Paterniani (1990) emphasized the remarkable contribution of the race Tuxpeño to increase the yielding potential of hybrids and open-pollinated varieties in Brazil. Brazilian maize hybrid programs pioneered the commercial utilization of semi-dent types. High levels of heterosis however, are not restricted to crosses involving contrasting endosperm types. Paterniani & Lonquist (1963) observed that expressed heterosis was as great between cultivars with similar endosperms as well as between those with contrasting endosperm types. These results indicate genetic variability among germplasms of similar endosperm types.

The need to keep the number of accessions in genetic banks in a manageable number is becoming more evident. In this way, an additional advantage of well succeeded pre-breeding programs is the establishment of core collections. The main goal of the core is to represent the genetic diversity of a crop species and its relatives with a minimum of repetitiveness. Brown (1989a) suggested that the core should consist of about 10% of the collection, which represents nearly 70% of the genetic variability. Moreover, the core should not exceed 3,000 entries. The establishment of these collections does not affect the base collection strategic role that is a source of replacement of the extensive genetic variability of different species (Vilela-Morales et al., 1997).

It is important to consider that a core collection is a dynamic rather than a static set of accessions. It is possible to introduce new accessions into the core and also replacements due to changes of breeder's needs. CIMMYT has developed efforts to establish maize cores. Results of a Tuxpeño core collection were reported by Crossa et al. (1994) and Taba et al. (1994).

METHODS

There are several alternatives for incorporating useful characteristics into adapted materials. The methodology depends on the heritability, gene action, number of genes involved, heterosis, and genotype x environment interactions. Whenever a superior germplasm is available from ongoing breeding programs, improvement by introgression is usually the least expensive and speedy method for improving the selected pre-breeding accessions (Eberhart et al., 1995).

The ideal proportion of exotics to be incorporated into adapted germplasms has been investigated by several researchers, but so far there is no conclusive information about this question. According to Bridges & Gardner (1987), it depends on the breeding goals (short or long term), and also on the performance of both exotics and adapted germplasms. Wellhausen (1965) recommended the incorporation of about 25% of exotic germplasm into Corn Belt adapted materials. Crossa & Gardner (1987) reported that populations with 75% and 100% of adapted germplasm did not differ in grain yield, being both populations superior to populations with 50% of adapted germplasm. Different levels of introgression (0, 25, 50, 75, and 100%) were evaluated by Michelini & Hallauer (1993), who observed that better yields were obtained in crosses with 50% exotic

germplasm, and also suggested the use of the exotic heterotic pattern Suwan-1 and Tuxpeño for further selection in U.S. Corn Belt breeding programs.

Backcrossing is an efficient way to transfer characteristics controlled by one or two genes, although it can be used also for higher number of genes, including quantitative characters. Thus, backcross has been used to improve adaptation of exotic germplasms. Eberhart (1971) suggested that the first backcross to adapted germplasm is the best base population to start selection. Degree of dominance and diversity of the parents affect the optimum number of backcrosses before initiating selection. In general, as the degree of dominance increases and as the parents become more diverse, additional generations of backcrossing before initiation of selection are required (Dudley, 1982). However, if exotic germplasms have been previously selected for adaptability, immediate positive effects can be obtained (Crossa et al.1987; Mungoma & Pollak, 1988). Considering the probability of fixing alleles, Crossa (1989) observed that if an exotic population has been selected for adaptability and should have high frequency of favorable alleles, the resulting population can be used directly as base population for selection. In the case backcross is used with the adapted parental, then an increase in population size is recommended in order to maintain the previously incorporated favorable alleles ungoma & Pollak, 1988).

USEFUL TRAITS FROM WILD SPECIES

Some traits present in wild populations are either absent or underrepresented in the domesticated form of *P. vulgaris*. A few of these are shown in Tables 2 and 3. Since wild beans have coexisted with pests and pathogens on an evolutionary time scale, they have developed pest and pathogen resistances, although at low frequency in their wild habitat, as known from the case of arcelin seed protein where only a few individuals in a population carry the resistant allele (Acosta-Gallegos et al., 1998). Wild common bean extends across many ecological niches including semiarid areas to moist tropical environments. To be able to colonize such diverse niches, wild common bean must possess a wide array of adaptive traits, some of which may be missing in cultivars because of the genetic bottleneck induced by domestication.

EFFORTS TO TRANSFER USEFUL TRAITS FROM WILD SPECIES INTO COMMON BEAN

Breeders recognize that a vast amount of genetic diversity within crop plants exists untapped in wild germplasm as a result of domestication (Frey 1975; Frey et al., 1984; Tanksley and McCouch, 1997). These wild relatives are a potential source of novel alleles that can be exploited for the improvement of yield and other quantitative traits in domesticated bean. Following are some examples from wild common bean.

RESISTANCE TO APION SPP

In the highlands of Mexico and Central America, two species of the Mexican bean pod weevil, *Apion godmani* Wagner and *A. aurichalceum* Wagner, attack domesticated common bean. Both species cause substantial damage in wild stands not only in common bean but also in related species. In beans grown under rainfed conditions in Durango, *A. godmani* caused yield losses of 60% (AcostaGallegos et al., 1992). Some resistance sources have been described in the cultigens and among wild accessions. Since wild beans are constantly exposed to the attack of this insect, sources of resistance should exist among wild accessions. The resistance seems to be effective since young pods are always exposed to the insects during the reproductive stage as a result of the climbing growth habit of the wild accessions. In the case of domesticated beans, pods are partially hidden under the canopy due to the prostrate growth habit of many cultivated types. Acosta-Gallegos et al evaluated accessions of pregnant women and more than 40% of nonpregnant women and preschool children are anemic. An interdisciplinary, international effort (Harvest Plus Challenge Program of the CGIAR, www.harvestplus.org) is under way to breed mineral- and vitamin-dense varieties of rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.), maize, beans, and cassava (*Manihot esculenta* Crantz) for release to farmers in developing countries. In the particular case of beans, this effort is called "Agrosalud" and is supported by the Canadian International Development Agency. We have been searching for mineral-dense bean *P. vulgaris* genotypes and, to date, higher Fe and Ca content has been detected in seeds of wild

beans as compared to those of domesticated landraces and bred cultivars (Espinosa-Alonso et al., 2006). Using a segregating population derived from a domesticated \times wild population, a few putative quantitative trait loci (QTL) associated with some of those compounds in the seeds were detected (Guzmán-Maldonado et al., 2003). Crossing between those high, mineral-dense wild bean genotypes with elite cultivars will be pursued in our local breeding program following the inbred backcross method or the recurrent backcross method (Wehrhahn and Allard, 1965). The inbred backcross method is useful for transferring polygenic traits such as N fixation capacity from exotic domesticated beans into bred temperate cultivars (Bliss, 1993), and root rot [caused by *Fusarium solani* (Mart.) Sacc. f. sp. *phaseoli* (Burk.) W.C. Snyder and H.N. Hans] resistance between gene pools (Román-Avilés and Kelly, 2005). Since these traits are polygenic, the method might also be useful for the transfer of other complex traits such as mineral content.

SEED YIELD

In contrast to pest resistance, which in the case of the *arcelin* gene is considered qualitative, yield-related traits are genetically much more complex and under the control of many genes that are also substantially influenced by environmental factors. Collectively, these genes are referred to as QTL. The use of wild germplasm for the improvement of yield in bean has been limited because the highly heritable, qualitative, morphological traits (domestication syndrome) that distinguish wild from domesticated germplasm, mask any alleles or QTL that might contribute positively to yield. A genotype, regardless of its inherent yield potential, will not reproduce if it does not flower. Thus, typically photoperiod-sensitive and viny wild germplasm does not appear to possess any desirable traits for the improvement of yield when grown in temperate production zones.

CONCLUSION

As pre-breeding is being carried out, the resulting materials are expected to have merit to be included in ordinary breeding programs, Pre-breeding refers to all activities designed to identify desirable characteristics and/or genes from unadopted (exotic or semi-exotic) materials

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