Genotype and environment interaction an alternative tool in plant breeding programs

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Abstract

The present paper reviews the genotype and environment interaction as an alternative tool in plant breeding programs for utilization of plant genetic resources. Environment has empirically been considered as a key factor by farmers and conventional plant breeders since agriculture began, but the use of environmental components of the collecting sites, in agro-biodiversity and breeding studies, has walked in very gradual steps. Environmental information on the collecting sites (eco-geographical characterization) reveals the adaptive range of species genotypes conserved and identifies the most important environmental components for adaptation. Application of geographic information system tools is useful to manage and analyse geo-referenced data of collecting sites, such as passport data and environmental variables, making so possible to study the environmental conditions under which crop wild relatives and traditional farmer varieties have acquired their adaptive traits. This can improve the efficiency of typical activities of the conservation and use of plant genetic resources, such as field explorations, priority sites for collecting germplasm, identification of gaps and priority areas of conservation. Assessment of genotype and environment interaction helps in identification of more adapted traditional farmers' varieties, in creating core collections and selecting appropriate germplasm for plant breeding programs.

Keywords: adaptive trait, farmer variety, genetic resources.

Introduction

Plant Genetic Resources (PGR) refers to genetic diversity (GD) of actual or potential value that exists among individuals or group of individuals belonging to a species, and is vital for crop improvement ensuring food security. They comprise GD contained in landraces populations and crop wild relatives (LPCWR), providing GD for crop improvement (Gixhari et al. 2016), abiotic-biotic stresses resistance, adaptation to climate change, etc. Breeders seek in gene bank for the best genotypes (parents) at various stages of plant breeding programme. Production factors as the reduction of land availability and suitable for agriculture, environmental degradation and global climate change are making breeders to identify adapted genotypes (AG) that can grow on delimitated growing factors as: poor soils, salt soils, drought, water logging, extreme temperatures, etc. (Ceccarelli, 1994; Ober & Luterbacher, 2002; Vinocur & Altman, 2005; Berger, 2007; Witcombe *et al.*,2008; Gixhari et. al. 2014).To identify the best genotypes breeders' need a high genetic representativeness (GR) in gene bank of GD in nature or in the field, and any information that may help to select parents with the desired traits.

The morphological phenotypic characterization and evaluation (C&E) of PGR, very useful to determine the GR in gene bank, have great importance in discovering the genes of interest for successful crop breeding. According to Kresovich *et al.*, (2006), C&E data without environmental components of collecting sites (ECCS) are not very useful for breeders. The most useful information on AG and bioclimatic factors that delimitates the distribution of one species, is related to the ECCS, which reveals the most important environmental components (EC) for adaptation and its impact on the heredity process. Application of geographic information systems (GIS), useful to manage geo-referenced data of collecting sites, enables to study the EC under which LPCWR have acquired their adaptive traits.

The aim of this review paper is to improve the efficiency of conservation and use of PGR(CUPGR) using simple complementary methodologies and cost-effective GIS tools that reveals the adaptation range of plant species and identifies the most important EC for adaptation and more AG of LPCWR, important for core collections, stable production and selecting appropriate parents (traits) for plant breeding (PB).

Subjects and Methods

Materials include literature published on management of PGR, C&Eof gene bank collections, conventional and molecular breeding, EC, plant adaptation, biotechnology, GIS and eco-geography applied to PGR. Comparison analysis, synthesis and interpretation of results found in research papers of respective fields were some of the methods use in this review.

Results and Discussion

Genotype and environment interaction. Since the publication of the genotype heredity concept (Johannsen, 1911), in the continuous challenge for plant breeders to solve the equation that relates phenotype (P), genotype (G) and environment

(E), the trend to understand heredity given by equation P = G + E (Fisher, 1918; Lande, 1980; Falconer & Mackay, 1996) has been the consolidation of genetic aspect of phenotype instead of recognizing the importance of environment on the heredity process. The development of plant bio-technology placed also the environment in a second place. Environment has empirically been considered as a key factor by farmers and conventional PB since agriculture began. Frankel & Benett (1970) explained the relationship between adaptation and GD and the importance of certain EC in the distribution of species. Actually, the EC are being selected as new future tools to improve the CUPGR.

In the final stages, breeders want to know, if their new variety behaves well in few or many environments and whether this behaviour is maintained for a long time. In conventional PB, the EC is determined by its impact on the phenotype expressed by interaction GxE. Thus, PB can take advantage of the adaptation range of LPCWR to detect the presence of interesting alleles in adaptive genes that can be transferred to modern cultivars (Bhullar et al. 2009).According to International Union for the Protection of New Varieties of Plants (UPOV, 2009)morphological characters remain the only legitimate markers accepted to approve a new variety. For this reasons the phenotypic information is the most used for C&E of germplasm and for the analysis of GD among plant species and within a species.

Geographic Information Systems and representativeness of gene bank collections. GIS tools are applied to *in situ* conservation of endangered wildlife in protected areas (Rodrigues et al., 2004), appropriate to conserve CWR. GIS tools manage information of ECCS under which LPCWR have acquired their adaptive traits. GIS analyse the spatial aspect of collecting sites, geographical distances (Hijmans & Spooner, 2001), and distribution of a particular group of species (Parra-Quijano *et al.*, 2003). GIS methodologies improve the GR of *ex situ* collections, the efficiency of CUPGR, the field explorations; identification of EC and geographic areas which are likely to contain specific desired traits of interest for breeders.GR of ex situ collections is the part of GD stored in gene bank. GR is highly related to the GD in nature or in the field, and it can be assessed using morphological, molecular and evaluation data. The assessment of GD of the populations in nature or in the field require expensive infrastructure, highly qualified personnel, its application is often difficult and an unattainable task.

According to Greene and Hart (1999) eco-geographical representativeness (ER), indirect reflects GR, due to the relationships among the EC of a site and the genotypes of the populations occurring at that site through natural selection and local adaptation. The term “eco-geographical” refers to combinations of climatic, ecological and geographical data related to patterns of genetic variation (Peeters et al., 1990). Thus, ER, based on the GxE interaction, can be useful in estimating the GR of collections using simple and cost-effective methods.

Plant adaptation and eco-geographical representativeness. Plant adaptation can be defined as the degree to which an individual or population is able to live and reproduce in a given environment with a unique combination of biotic and abiotic stresses (Allard 1988).Environment has direct influence on the phenotype and shapes genotypes through adaptation. Collected germplasm covering all adaptation range of a species’, help breeders to detect the presence of adapted genotypes able to grow in extreme environments. *Aegilops* species, having wide genetic variation for diseases resistance, for drought (Mólnar et al., 2004) and salt tolerance (Farroq, 2002) are a highly-valued source of genes for PB (Rao and Hodgkin 2002).

Climate change is redirecting PB to develop crops that are more tolerant to abiotic stresses such as drought, flooding, heat, radiation, salinity, chilling and freezing (Rai and Srivastava 2001; Vinocur and Altman 2005). Consequently, ER studies, due to the close relationship between EC and genetic patterns (Allard 1988), are essential to improve the CUPGR, and to measure the AG captured in gene banks (Parra-Quijano et al. 2008).

Future prospects

Eco-geography and GIS (Eco-GIS) tools are helpful for the collecting, conservation, efficient uses of PGR, regeneration, plant breeding, precision agriculture, environmental conservation, rural development, and on farm. Using the coordinates of the collection sites, Eco-GIS tools provide the link between genotypes and the environment, helping to select sets of germplasm containing specified traits. Each collection site can be individually profiled for available EC as precipitation, humidity, temperature, agro-climatic zoning, and soil characteristics. Eco-GIS tools are able to identify the most suitable sites for conservation and regeneration, as a key factor in reducing genetic erosion. An increase of Eco-GIS tools in CUPGR is expected in the present decades, particularly as regards the challenges implied by global climate change for agriculture. Furthermore, studies on adaptation of LPCWR should continue to increase the importance of the EC in explaining the phenotype, the abiotic-biotic aspect of adaptation, and the influence of farmers on the eco-geographical patterns of cultivated plants.

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