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Study of statistic stability to select high-yielding and stable peach genotypes

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ABSTRACT

In peach breeding, suitable identification methods for performance stability studies as well as the associations between stability parameters are poorly understood. Therefore, the aims of this work were to compare parametric (S^2_{ij}, $b_iS^2_{xi}$, W_i, θ_i and I_i) and non-parametric ($S_i^{(1)}$, $S_i^{(2)}$, $S_i^{(3)}$ and P_i) stability measures, evaluate the level of association among them, select superior accessions and identify major environmental variables as causes of yield variation among years. Fruit yield stability was studied using data of fruit yield from 25 peach genotypes under three environments, arranged in a completely randomized design with three replications. Frosts, chilling, heat, rainfall and the interactions among them were considered as explanatory variables of yield variation through years. Crossover was the main effect of genotype-by-environment interaction indicating that the selection of high-yielding and stable peach genotype would be a laborious task for breeders. The interaction between rainfall and heat accumulation during fruit development period explained 96.7% of yield variation among years. Yield (Y_i) exhibited negative correlation with W_i and θ_i, while W_i showed negative association with P_i. $S_i^{(1)}$, $S_i^{(2)}$, and $S_i^{(3)}$ were positively associated with each other, showing that just one of these three statistics would be sufficient to select stable accessions although they were not correlated with Y_i. Fruit yield was positively correlated with P_i and I_i, these two measures were also positively associated with each other, and therefore, only one of them would be enough for selection of superior peach accessions. Both, P_i and I_i statistics revealed that accessions Sunprince, Flameprince, María Aurelia, Vega, Starlite and Flavorcrest were the most stable and high-yielding genotypes across environments.

1. Introduction

Prunus persica (L.) Batsch is one of the most important fruit tree species of the Rosacea family. Among the semi-perennial fruit trees, peach ranks third in the world, and Argentina is the eleventh largest producer with 285,000 tons per year FAOSTAT (http://faostat.fao.org/). The northeast of Buenos Aires province, Argentina, represents one of the most important peach producing regions of the country. San Pedro Agricultural Experimental Station of the National Institute of Agricultural Technology (INTA San Pedro) is located there and has a collection of peach and nectarine accessions introgressed from different regions around the world which is evaluated for yield and quality traits every year. Peach is a crop subjected to an intense breeding activity that allows a fast turnover of varieties, since new cultivars are being created continuously all over the world. However, despite tremendous progress in the selection of superior and high-yielding cultivars, new materials are constantly demanded by both farmers and consumers, and hence further selection activities are necessary. New cultivars for horticulturists and potential parents for breeding programs are selected from a collection of genotypes with diverse pedigree and origin. Since each genotype interacts with several climatic variables, differential performance is expected when a genotype has been selected in one environment and is cultivated in another. This genotype-by-environment interaction (GEI) is a particular problem for plant breeders (Giauffret et al., 2000).

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Non-crossover and crossover are the main effects of GEI (Cruz and Regazzi, 1997). The latter is responsible for the lack of correlation among phenotypic values and changes in genotype ranks masking the potential utility of exotic materials (Giauffret et al., 2000). GEI affects the extent of genetic progress through plant breeding and also disturbs the efficiency of varietal choice for farmers (Becker, 1981). From farmers' standpoint, fruit yield stability is important since horticulturist's major concern is to minimize the chance of poor yield in a particular year. Peach varieties are used as semi-perennial crops, which remain in production for more than 10 years. For this reason, the choice of varietal types with high yield and stability through years would be of utmost importance for peach growers. Lin et al. (1986) identified three concepts of stability, type 1, 2 and 3. Type 1 is also called static (Becker and Leon, 1988) and is useful when considering quality traits, disease resistance or stress characters that should not vary among different environments. Coefficient of variability (Francis and Kannenberg, 1978) and genotypic variance across environments (S^2_{xi}) (Roemer, 1917) are the most common methods associated to type 1 or static stability. Type 2 stability is also called dynamic or agronomic stability (Becker and Leon, 1988). According to this concept, a stable genotype has no deviation from the general response and thus it has a predictable behavior. This concept is accepted by breeders and agronomics, who prefer developing genotypes with high-mean yields and potential to respond to agronomic inputs or better growing conditions (Becker, 1981). Plaisted and Peterson (1959), and Wricke's ecovalence (1962) are based on analysis of the variance (ANOVA) and are used to measure the type 2 stability. Regression methods were also proposed to measure stability (Eberhart and Russell, 1966; Finlay and Wilkinson, 1963). In this methodology the stability is expressed in terms of three empirical parameters: mean yield, the coefficient of regression, b_i, and the sum square deviation from regression, (S^2_{ij}) (Crossa, 1990; Flores et al., 1998). The S^2_{ij} is strongly related to an unpredictable part of genotype variability and is considered a stability parameter, and b_i characterizes the specific response of genotypes to environmental effects and may be used as a response parameter (Breese, 1969). Genotypes which do not react to environmental factors variations show zero b_i values and would be stable according to the static concept or type 1 stability. On the other hand, genotypes possessing an average response to environmental changing conditions show b_i values equal to one, according to the agronomic concept or type 2 stability. Although the regression methodology is frequently applied to study stability, its coefficient b_i could be biased because the independent variable of the regression analysis, which in this case is the environmental mean, should be measured without error. As this assumption could not be met (Sprent, 1969), it may be considered a serious limitation. Furthermore, the variation of the regression coefficients estimates is usually so small that complicates ranking genotypes based on stability (Farias et al., 1995). Yue et al. (1997) considered the need for satisfying the assumption of normality, the variance homogeneity, the additivity or linearity of genotypes and environmental effects, as well as additional constraints of parametric methods. Since practical interest in combining mean yield and stability in one parameter, based on the safety first-rule (Kataoka, 1963), Eskridge (1990) proposed the use of the yield reliability concept or reliability index (I_i), which is calculated through the consistent high yields across environments.

An alternative for the assessment of a cultivar performance considering GEI with no limitations inherent to the use of regression or ANOVA are the non-parametric methods. They are distribution-free, unlike parametric statistic they do not make any assumptions, are easy to use and their results are simple to interpret (Nassar and Huehn, 1987; Huehn, 1990a). Lin and Binns (1988) proposal is infrequently quoted in the literature, but it is a good alternative for the assessment of cultivar performance in the presence of GEI. Like reliability index (I_i), it characterizes genotypes with a single parameter (P_i) by associating stability and productivity, and defines a superior cultivar as a genotype whose performance is near the maximum in various environments (Lin and Binns, 1988; Helgadóttir and Kristjánsdóttir, 1991). This definition of superiority is similar to the breeder's objective, since a superior cultivar should be among the most productive all over the possible environments (Farias et al., 1997). Other non-parametric procedures are based on the comparison of genotype ranks in each environment; genotypes with similar ranks across environments are considered stable (Huehn, 1979; Nassar and Huehn, 1987). Huehn (1990a) proposed the following non-parametric measures of phenotypic stability $S_i^{(1)}$, $S_i^{(2)}$, and $S_i^{(3)}$ and defined a stable genotype as that whose position in relation to the others remains unaltered in the set of environments assessed. In contrast to parametric models, this method reduces the bias caused by points outside the adjusted regression equation. The addition or removal of one or few genotypes probably causes less variation in estimates of stability parameters than parametric methods.

Although several models have suggested measuring yield stability and have broadly been used in major crops, they have been poorly applied to understand the nature of GEI in peach. Each methodology shows different aspects of stability but no single method can adequately explain cultivar performance across environments. Evaluation and comparison of various methodologies for stability analysis in peach have not been performed yet. On the order hand, the level of association among stability measures obtained by different models should be considered because it could provide complementary information related to genotype behavior and helps the breeder to choose the best genotype. Association between yield and climatic conditions would provide not only an assessment about the performance and adaptation of accessions, but also reliable information from the perspective of global climate change under different scenarios (Rea and Eccel, 2006). Peach yield is highly correlated with the number of flowers (Okie and Werner, 1996) arising after dormancy period. Dormancy is an important adaptive mechanism that allows the plant to survive under unfavorable conditions during winter. During this period, several events occur simultaneously. Water is important for bud and plant development since it is involved in solute translocation, enzymatic reactions and osmotic regulated events, reason why many studies are focused on its dynamics (Yamamoto et al., 2012). Lang et al. (1987) divided the dormancy period in paradormancy, endodormancy and ecodormancy. Paradormancy refers to correlated inhibitions organ by organ; while in the endodormancy state, the meristem is rendered insensitive to growing-promoting signal (Rohde and Bhalerao, 2007) until the chilling requirement (CR) is completed. During ecodormancy, bud growth mostly depends on heat accumulation, so growing speed increase considerably in warm temperature. Once heat requirement (HR) is fulfilled, blooming takes place. Both traits, CR and HR are determining factors for adaptation (Richardson et al., 1975; Citadin et al., 2001) because lack of chilling or heat results in abnormal patterns of budbreak and fruit development. For successful production, accessions must be chosen to match the thermal regime of a particular location so that adequate chilling is received for normal development but bloom is late enough to avoid frost (Okie and Blackburn, 2011).

The aims of this work were to (i) compare parametric and non-parametric stability statistic of 25 peach accession data sets collected from different environments and evaluate the level of association among stability measures, (ii) select promising high-yielding and stable accession to incorporate into peach germplasm