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Correlations between quantitative tree and fruit almond traits and their implications for breeding

K. Sorkheh[a], B. Shiran[a,*], M. Khodambashi[a], H. Moradi[b], T.M. Gradziel[c], P. Martínez-Gómez[d]

[a] Department of Agronomy and Plant Breeding, Faculty of Agriculture, Shahrekord University, Shahrekord, Iran
[b] Section of Horticulture, Agriculture and Natural Resources Research Centre of ShahreKord, Iran
[c] Department of Plant Science, University of California, Davis, CA 95616, USA
[d] Department of Plant Breeding, CEBAS-CSIC, 3000 Espinardo, Murcia, Spain

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ABSTRACT

Correlations between 29 quantitative tree and fruit traits were studied in 46 almond genotypes and some inter-specific crosses. Results reflected a significant diversity in the assayed almond germplasm. In addition, the obtained cluster demonstrated varying degrees of relationships, illustrating higher correlation values for the flowering traits and lower correlation values for the nut and kernel traits. To determine the importance of the traits and the levels of similarity existing between the various studied traits, a discriminate analysis was carried out. According to the results obtained from these analyses, the different traits were discriminated on basis of the characteristics of the presence of double kernels, the nut and the kernel size, the flowering date, kernel yield and shelling percentage. Finally, this study evidenced correlations between most of the agronomic traits in almond, although the correlations coefficient (r) value was found to be higher than 0.5 only in some cases. This analysis can help breeders for choosing the most favorable entries to build a core subset of the almond collection for the purpose of breeding.

1. Introduction

For almond [*Prunus dulcis* (Mill.) D.A. Webb] breeding programmes, the knowledge of the relationships that exist among the quantitative traits, which must be improved, is of significant interest as the choice of one characteristic can favor the appearance or disappearance of others affecting the efficiency of the program (Dicenta and García, 1992; Dicenta et al., 1993a). Moreover, the presence of significant correlations among traits and their assessment would facilitate an advanced procedure of indirect selection aimed at improving a character by selecting it over another. This improvement is significant for recognising and enhancing those traits, which are difficult to identify during the segregation of the offspring or for conducting an early selection procedure in cases where a characteristic is not manifested until the sexual maturity of the tree (Vargas and Romero, 2001).

The presence of a high value of phenotypical correlations among the traits can be attributed, at least in part, to the pleiotropic effects or linkages that exist among the genes that influence the different characteristics (Hansche et al., 1972). Several authors have recognized that the knowledge of the correlations and relationships present among important agronomic traits that need to be improved is quite significant (Hansche et al., 1966). In addition, some other authors have also determined the existence of other relationships among the fruit traits in almond (Kester, 1965; Spiegel-Roy and Kochba, 1981). Further, the most important objectives of the almond breeding programmes entail the evaluation of late blooming and its transmission; the blooming density and productivity; the time of maturity; as well as the transmission of some fruit and kernel traits (Kester, 1965; Spiegel-Roy and Kochba, 1974, 1981; Kester and Asay, 1975; Kester et al., 1977a,b; Socias i Company et al., 1999; Sánchez-Pérez et al., 2007). In addition, Moradi (2006) studied several quantitative traits in the cultivated almond genotypes that were evaluated for the purpose of assessing the almond genotypes. This investigation was carried out in order to evaluate and compare 11 almond cultivars in Emamie station at Chaharmahal va Bakhtiari province. The experiment was done in a randomized complete block design (RCBD) with 3 replications. In the first stage trunk diameter, tree height and annual shoot growth were evaluated. Trunk diameter did not show any significant differences but annual shoot growth and tree height showed significant differences among cultivars at 1% level. Three years evaluation of cultivars reproductive characteristics showed differences in blooming date, fruit and kernel yield, characteristics of fruit and kernel.

It is noted that since the selection of a given trait could favor the presence of another desirable or undesirable characteristic in

* Corresponding author at: Department of Agronomy and Plant Breeding, Faculty of Agriculture, Sharekord University, P.O. Box 115, Shahrekord, Iran.
E-mail address: shiran@agr.sku.ac.ir (B. Shiran).

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Table 1
Almond genotypes and interspecific crosses assayed including the origin, pedigree and main agronomic traits.

Genotype	Origin	Main agronomic traits			
		Pedigree	Shell	Compatibility	Flowering[b]
'Monagha'	Iran	Unknown	Soft	Self-incomp.	Early (−6 and earlier)
'Sefied'	Iran	Unknown	Soft	Self-incomp.	Early (−6 and earlier)
'Mamaei'	Iran	Unknown	Hard	Self-incomp.	Middle (0 to +2)
'Rabei'	Iran	Unknown	Hard	Self-incomp.	Middle (0 to +2)
'Shekofeh'	Iran	Ai × Nonpareil (o.p)[a]	Semi-hard	Self-incomp.	Late (+5 to +7)
'Azar'	Iran	Ai × Cristomorto	Semi-hard	Self-incomp.	Late (+5 to +7)
'Sangi 31'	Iran	Unknown	Hard	Self-incomp.	Early (−6 and earlier)
'Sangi 13'	Iran	Unknown	Hard	Self-incomp.	Early (−6 and earlier)
'Sangi 14'	Iran	Unknown	Semi-hard	Self-incomp.	Early (−6 and earlier)
'Sangi 28'	Iran	Unknown	Hard	Self-incomp.	Middle (+ to +2)
'Sangi 12'	Iran	Unknown	Hard	Self-incomp.	Late (+5 to +7)
'Sangi 26'	Iran	Unknown	Hard	Self-incomp.	Early (−6 and earlier)
'Cosimo di Bari'	Italy	Unknown	Hard	Self-incomp.	Middle (0 to +2)
'Fileppo Ceo'	Italy	Unknown	Hard	Self-incomp.	Late (+5 to +7)
'Kapareil'	USA	Nonpareil × Eureka (BC)	paper	Self-incomp.	Middle (0 to +2)
'Tuono'	Italy	Unknown	Hard	Self-comp.	Late (+5 to +7)
'Moncayo'	Spain	Unknown	Hard	Self-incomp.	Late (+5 to +7)
'Texas' ('Mission')	USA	Unknown	Semi-hard	Self-incomp.	Late (+5 to +7)
'Lauranne'	France	Ferragnes × Tuono	Hard	Self-comp.	Late (+5 to +7)
'IXL'	USA	Unknown	Soft	Self-incomp.	Middle (0 to +2)
'Primorski'	Ukraine	Princesse2077 × Nickitsky(BC)	Soft	Self-incomp.	Very late (+8 and later)
'Tardy Nonpareil'	USA	Mutant of Nonpareil	Soft	Self-incomp.	Very late (+8 and later)
'Princesse'	France	Unknown	Semi-hard	Self-incomp.	Middle (0 to +2)
'Genco '	Italy	Unknown	Hard	Self-comp.	Late (+5 to +7)
'Fascionello'	Italy	Unknown	Hard	Self-incomp.	Very early (−6 and earlier)
'Thompson'	USA	Texas(Mission) × Nonpareil	Soft	Self-incomp.	Late (+5 to +7)
'Ferragne's'	France	Cristomorto × Ai	Soft	Self-incomp.	Late (+5 to +7)
'Ne Plus Ultra'	USA	Unknown	Soft	Self-incomp.	Middle (0 to +2)
'Nonpareil '	USA	Unknown	paper	Self-incomp.	Middle (0 to +2)
'Shahrodi 18'	Iran	Unknown	paper	Self-incomp.	Middle (0 to +2)
'Shahrodi16'	Iran	Unknown	Soft	Self-incomp.	Very late (+8 and later)
'Shahrodi 8'	Iran	Unknown	Hard	Self-incomp.	Late (+5 to +7)
'Shahrodi 17'	Iran	Unknown	Semi-hard	Self-incomp.	Middle (0 to +2)
'Shahrodi 21'	Iran	Unknown	Semi-hard	Self-incomp.	Middle (0 to +2)
'Shahrodi 12'	Iran	Unknown	Hard	Self-incomp.	Late (+5 to +7)
'Shahrodi 15'	Iran	Unknown	Paper	Self-incomp.	Late (+5 to +7)
'Shahrodi 13'	Iran	Unknown	Soft	Self-incomp.	Late (+5 to +7)
'Shahrodi 6'	Iran	Unknown	Semi-hard	Self-incomp.	Late (+5 to +7)
'18-G-k1'	Iran	Almond × peach	Semi-hard	Self-comp.	Early (−6 and earlier)
'131-G-k2'	Iran	Almond × peach	Hard	Self-comp.	Early (−6 and earlier)
'91-G-k3'	Iran	Almond × peach	Soft	Self-comp.	Early (−6 and earlier)
'58-G-k4'	Iran	Almond × peach	Soft	Self-comp.	Early (−6 and earlier)
'84-G-k5'	Iran	Almond × peach	Semi-hard	Self-comp.	Early (−6 and earlier)
'123-G-k6'	Iran	Almond × peach	Semi-hard	Self-comp.	Early (−6 and earlier)
'52-G-k7'	Iran	Almond × peach	Hard	Self-comp.	Early (−6 and earlier)
'85-G-k8'	Iran	Almond × peach	Soft	Self-comp.	Early (−6 and earlier)

[a] o.p = open pollinated, open pollinated parent unknown; BC –backcrossed.
[b] The number in the parentheses indicate the days before (−) or after (+) peak "Nonpareil" bloom (Asai et al., 1996, Almond Production Manual. University of California. ANR Publication).

almond, the existence of a close relationship between the traits could facilitate or hinder the breeding process (Dicenta and García, 1992). In this context, several breeding programmes were initiated at the Agriculture and Natural Resources Research Centre (ANRRC) of Iran, in order to associate and evaluate the high quality of Iranian genotypes comprising the traits of late flowering, self-fertility and characteristics of sweet kernels with foreign cultivars that possess a good rate of production and high quality, such as 'Mamaei', 'Shekofeh' or 'Azar'. Sorkheh et al. (2007) conducted studies to assess morphological and molecular characterization of the almond genotypes on both. On the other hand, the multivariate techniques can help evaluate large sets of data by breaking down several phenotypic and genotypic measurements into fewer and concise, more interpretable, and more easily visualized groups (Souza and Sorrells, 1991; De Giorgio and Stelluti, 1995; Ahmad et al., 1997).

The aim of the present study was to assess the important quantitative tree and fruit traits of different almond genotypes and inter-specific crosses and ascertain the correlations and relationships that exist between these traits.

2. Materials and methods

2.1. Plant material

The plant material examined was obtained from ANRRC in Shahrekord, Iran. The name, origin and other main agronomic characters of the 46 assayed genotypes are reported in Table 1 including the 8 inter-specific almond × peach genotypes generated by forming several backcrosses with almond genotypes.

2.2. Evaluation of quantitative tree and nut traits

Twenty-nine quantitative tree and fruit traits were evaluated according to the protocols given by Dicenta and García (1992), Moradi (2006) and Sánchez-Pérez et al. (2007) (Table 2). Each genotype was represented by 3 contiguous 10-year-old trees planted on an experimental plot. In addition, the traits of the fruit (nut and kernel) were evaluated at a maturity state in a sample containing 30 fruits of each genotype.