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Relationships of morphological traits and ripening time during juvenile phase in apple

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ABSTRACT

Young progenies were appraised with relative bearing parents for values of specific morphological traits related to earliness trait in order to defeat the juvenile period in breeding program. 38 Iranian local and imported apple cultivars with different times of ripening, from very early to very late, selected as parents to produce high yielding early descendents were formerly propagated on MM111 clonal rootstocks, grown in the identical pedo-climatic conditions. So, all the parents were classified in 3 distinct classes of earliness including very early–early ripening, mid ripening and late–very late ripening. The 3-year-old *True-to-Type* plants of the same parents were exploited for comparative biennial studies of 10 definite vegetative traits, defined as morphological markers, with their parents to estimate probable correlations with earliness character as the target of the current apple breeding program. Stepwise regression analysis revealed leaf length as the first trait entered to the model explaining approximately 45% of variations. Maximum and minimum direct effects obtained from path analyses for ripening time were deduced 8.71 and −7.47 for leaf length and leaf width, respectively. Maximum indirect effect belonged to leaf width through leaf length (8.17). Cluster analysis according to UPGMA procedure and principal component analysis (PCA) was used for classifying cultivars and assessment of the traits. According to the results of cluster analysis, high variability among the groups of cultivar was determined by ripening time and origin or geographic distribution. As a result, the early ripening cultivars were placed in opposite side of cluster related to the late cultivars. Furthermore, four efficient factors (traits) including total leaf chlorophyll content, leaf length, leaf width and pedicle length justified 87% of existing diversity based on factor analysis.

1. Introduction

Apple (*Malus* × *domestica* Borkh.) is an important fruit crop of temperate zones and a large number of commercial cultivars are available as chance seedling because of the spread allogamy and controlled crosses (Baldini, 1981). The progenitor species of this interspecific hybrid complex of allopolyploid origin is thought to be *Malus sieversii* (Lodeb.) Roem., hybridized with both European and Asian species throughout its domestication (Badenes and Byrne, 2012). Main vegetative and pomological traits of 2000 apple cultivars are described (Morgan and Richards, 2002). Evaluation of the existing cultivars is indispensable for successful breeding programs and nursery management (Goulão and Oliveira, 2001). Mature trees of 92 native and imported apple cultivars were widely evaluated studying phenology, pomology and morphological traits in Karaj (Iran) climatic conditions (Hajnajari, 2008). Though the major part of diffused apple cultivars are late ripening, it seems important to produce cultivars presenting higher class of earliness (Janick et al., 1996). Long juvenile period in apple (Visser and Schaap, 1967), inhibits fast results in fruit breeding where investigations on morphological traits seem the requisite of modern programs of apple genetic improvement that aim high quality crop with low production costs (Brown, 1975). However, one of the drawbacks of fruit breeding for quantitative traits is the long juvenile period of the seedlings. This physiological barrier in offspring obliges apple breeders to seek new approaches such as morphological traits that may be in correlation with earliness trait in mature phase to carry out the breeding programs quickly (Kazlovskaya, 2005; Kenis and Keulemans, 2007). Importance of morphologies led to deduce that leaf characteristics are better morphometric discriminators for chestnut genotypes (Serdar and Kurt, 2011). High significant correlation ($r = 0.98$) was observed between branch distance along

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Table 1
Classification of the studied apple cultivars according to the time of ripening (early–late ripen).

No.	Class	Cultivar	No.	Class	Cultivar	No.	Class	Cultivar
1	Very early–early ripen cultivars (R1)	Golab-e Sahne	14	Mid ripen cultivars (R4)	Nayan-e Arange	26	Late ripen cultivars (R6)	Idared
2		Yellow Transparent	15		Ardabil No. 2	27		Scarlett Wilson
3		Haji-e Karaj	16		Stayman	28		Golden Delicious
4	Early ripen cultivars (R2)	Golab-e Kohanz	17		Ghermez-e Rezaie	29		GoldJon
5		Mashhad Nouri	18		Gravenstein	30	Late–very late ripen cultivars (R7)	Prime Gold
6		Shafei	19	Mid–late ripen cultivars (R5)	Early Red One	31		Red Rom Beauty
7		Kompouti	20		Red Chief	32		Starking
8	Early–mid ripen cultivars (R3)	Sheikh Ahmad	21		Red Spur	33		Top Red Delicious
9		Sultani-e Shabestar	22		Red Delicious	34		Granny Smith
10		Khorsijan	23		Bell de Pontoize	35		Ganny Beauty
11		Koli Mohalat	24		Golden Smoothee	36	Very late ripen cultivars (R8)	Akhlemad-e Mashhad
12		Heidarzade	25		Glockenapfel	37		Yellow Spur
13		Jonathan				38		Bell de Boskoop

seedling stem and number of branches (Hajnajari et al., in press, 2012). Correlations may be developed and may link vegetative traits with productive ones. Significant correlations ($P > 99\%$) were determined between earliness and hypocotyl length ($r = 0.92$) in *Citrullus lanatus* (Onsinejad and Abak, 1999). Three of the phenological traits, time of stigma exertion, time of catkin elongation and time of leaf bud break were highly and positively correlated in hazelnut (Yao and Mehlenbacher, 2000). Three wild Pyrus and 46 cultivated Pyrus pyrifolia cultivars were selected to examine cell number and cell size at the time of pollination and fruit harvest. It was found that Late-maturing cultivars had larger cells than earlier cultivars (Zhang et al., 2006). Visser (1965) and Visser and Vries (1970) declared existence of positive correlation between juvenile phase duration and earliness. Visser (1965) gained a negative correlation between seedling vigor and length of juvenile phase in apple and pear trees. Visser et al. (1976) also reported a significant negative correlation between tree size and duration of the juvenile phase. Bagnara et al. (1994) investigated juvenile and adult phase in pear and found various significant correlations. Hjeltnes (1988) reported that a juvenile habit based on the several feathers can also been proposed as a pre-selection criterion. He also found several significant correlations between morphological traits and earliness in pear (Hjeltnes, 2004). 3000 apple hybrid progenies were studied previously for the same marker traits correlations with their relative parents (Hajnajari et al., in press, 2012), and earliness heritability estimation in parents and F1 progenies (Hajnajari et al., in press, 2012). Present study denotes probable correlations between morphological characters and earliness trait by comparing bearing parents, divided in three different classes of earliness, with similar gene pool young Trees 3- and 4-year-old propagated asexually on MM111 clonal rootstocks. Parents were contemporaneously assessed both in juvenile and mature phase for probable correlations by use of marker traits for earliness.

2. Materials and methods

2.1. Plant material

The breeding program was carried out on 38 mature apple cultivars (Table 1) grown in Kamal Abad Research Station located in Karaj, North West of Tehran Province, Iran (latitude 35°48′N and longitude 51°2′E), in 2004. The selected parents with far geographical origins comprised different ripening time, from very early to very late. The breeding object consisted of production of new early ripening cultivars and there was necessity to overcome time consuming juvenile phase of the offspring as the main obstacle excluding grafting scions on clonal rootstocks due to large number, 7000, of progenies. This study was conducted mainly on True-to-Type propagated 3- and 4-year-old plants of the parent cultivars (Table 1) grafted on MM111 clonal rootstocks at juvenile phase beside 16- and 17-year-old mature trees of the same cultivars. Those morphological traits showing high positive correlation with earliness may be consequently used steadier as vegetative markers with the least risk of gene loss in screening of juvenile progenies.

2.2. Research method

Classes of earliness in mature trees for the parent cultivars were formerly registered based on the number of days from full bloom to ripening time and maturity indices. The cultivars were divided into 5 and 9 classes according to harvest (maturity) time, and ripening time respectively, based on international and national apple descriptors (Watkins and Smith, 1982; Hajnajari et al., 2008). Due to the prevalent ripening phenologies, the selected parents were classified in three distinct classes of earliness comprising very early–early ripening, mid ripening and late–very late ripening cultivars. We estimated relations between the morphological traits including Tree height (SH), leaf length (LL), leaf width (LW), length of pedicle (LP), rate of leaf chlorophyll (RLC), annual growth rate (AGR), number of branches (NB), branches distance along the stem (BD), branch angle related to stem (BAS), trunk diameter (TD) in True-to-Type propagated 3- and 4-year-old plants and non vegetative trait of bloom period (BP) related to the very important trait of ripening time (RT) in the 16- and 17-year-old mature parent trees as the current apple breeding objective. The under study characters were measured visually and or by instruments in six replications on 3- and 4-year old of parent plants in juvenile phase and 3 replications on 16- and 17-year old of bearing parent trees in two subsequent years.

2.3. Data analysis

Analysis of variance, correlation analysis and multivariate analysis were performed. Morphological and phenological data were analyzed using Pearson correlation analysis. The SAS 9.1, PATH2 and NTSYSpc software's were used. Cluster analysis (Cruz and Regazzi, 1994), path analysis (Wright, 1921) and principle component analysis (PCA) (Sneath and Sokal, 1973; Iezzoni and