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Evaluation of Some Vegetative and Reproductive Characteristics of Select Local Pears (*Pyrus* sp.) in Guilan Province, Iran

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ABSTRACT

Wild (local) pears (*Pyrus* sp.) that grow in Guilan, a province in the north of Iran, are locally called 'Khoj'. Despite their extensive diversity, little is known about these kinds of pears. This research was conducted over two years to evaluate various aspects of pear-tree growth and development of genotype characteristics of 10 select local pears in the Fouman region located in Guilan province. Canopy shape varied from right in 'Latanz' to flat in 'Arbakhoj'. 'Latanz' fruit had the largest and the earliest ripening fruits. In contrast, 'Zizaling' produced the latest-season fruits. 'Latanz' flower had 10 petals, whereas the corolla of remaining genotypes consisted of five petals. Least diversity was observed in the scales and spines on the tree trunk; however, most diversity was found in growth traits. Among 9 traits related to leaf, leaf length to width ratio and shape of the leaf base and tip had more diversity than other traits and could be used to distinguish the 10 genotypes based on DUS. Among different tree organs, most characteristics were observed in fruits and varieties of fruit size, position of maximum diameter, fruit color, sepal mode, and time of ripening, these being the most distinguishing traits of all 10 genotypes. Cluster analysis (using Ward's method) based on some fruit traits, genotypes were grouped into three clusters: large, medium, and small.

Keywords: descriptor, genotypes, local pear, phenotypes, wild pears
Abbreviations: DUS: National Guidelines for Testing Distinctness, Uniformity and Stability; **UPOV**: International Guidelines to Protect Plant Varieties

INTRODUCTION

Pear belongs botanically to the Rosaceae family, Pomoideae subfamily, *Pyrus* genus and also is one of the most economically important tree fruit crops in temperate zones (Bao *et al.* 2008). After apple, pear is the most important pome fruit that grows in all temperate regions of the world. Most *Pyrus* species and cultivars are self-incompatible and inter-cross is a natural common practice. Consequently, considerable taxonomic hybrids may be found. Identification of species based on morphological characteristics is not reliable because of segregation which occurs in the progeny (Sharifani *et al*. 2008). *Pyrus* species, with thousands of cultivars, can be traditionally divided into two native groups according to their geographic distribution: Occidental pears and Oriental pears. In contrast to the single cultivated species *P. communis* L. in Occidental pears, at least three species, namely, *P. ussuriensis* Maxim, *P. sinkiangensis* Yu, and *P. pyrifolia* Nakai are involved in the origin of pear cultivars in oriental pears (Bao *et al*. 2008). Commercial pear production is mainly represented by two species including *P. communis* L., *P. pyrifolia* and *P. communis* (European pear), which is the most commonly cultivated pear species in Europe, North America, North Africa, and temperate regions of the south hemisphere, while *P. pyrifolia* Nakai is the main cultivated pear species in Asia (Brini *et al*. 2008).

P. communis cv. 'Williams' was chosen and commercialized in Europe in the 18th century; it is also known as 'Bartlett' or 'Yellow Bartlett' in North America. 'Max Red Bartlett' was discovered in the past century from a bud mutation of 'Williams' which caused red skin pigmentation. The 'Williams' fruit is green at maturity, with a little blush on the sun-facing side, and later turns yellow when fully ripe. In contrast, 'MaxRed Bartlett' fruit is dark red, almost purple, throughout maturation, but then the intensity of this coloration decreases and the fruit turns bright scarlet when ripe. This mutation is unstable and is known to revert from the 'Max Red Bartlett' to the 'Williams' phenotype in all branches, or individual fruits, where it may involve sectors of fruit skin or its whole surface (Pierantoni *et al*. 2010).

Based on the geographic distribution and species involved, pear cultivars native to East Asia can be divided into five major groups: Ussurian pears, Chinese white pears, Xinjiang pears, Chinese pears and Japanese pears. The former four types have been developed in China and the later one is cultivated in Japan. Ussurian pears have been derived from wild *P. ussuriensis* that is naturally distributed in northeastern China. Xinjiang pear (*P. sinkiangensis*) is native to Northwestern China and the origin is an interspecific hybridization involving Chinese white pears or Chinese sand pears and Occidental pears. *P. sinkangensis* cultivars vary considerably, combining characteristics of both *P. communis* and Chinese white pears. Chinese sand pear cultivars have undoubtedly originated from *P. pyrifolia* occurring mainly in Changjiang River valley, China. Chinese white pear cultivars have traditionally been assigned to *P. bretschneideri* Rehd by Chinese taxonomists and horticulturists. The origin of Chinese white pears might be involved in the hybridization of *P. ussuriensis* and *P. pyrifolia* (Bao *et al*. 2008).

Japanese pear (*Pyrus pyrifolia* Nakai) is one of the most important fruit crops in Japan. Most cultivars of Japanese pear show self-incompatibility. Therefore, artificial pollination by hand with compatible pollen using a conventional feathered stick is usually carried out for commercial production. As an alternative technique, spray pollination using aqueous pollen grain solutions is expected to reduce labor and costs in fruit tree cultivation (Sakamoto *et al*. 2009). *Pyrus caucasica* Fed. and *P. pyraster* (L.) Burgsdare regar-

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Original Research Paper

ded as the main wild ancestors from which the cultivated European pear (*P. communis* L.) has probably evolved. *P. caucasica* ('Panta' in Georgian) is an endemic species of the Caucasus. Its occurrence outside of the Caucasus region might be explained by planting of this tree in Soviet times in orchards and forest gardens for producing vegetative and generative rootstocks for fruit trees. Originally, it was distributed in natural habitats of broad-leaved and mixed coniferous forests at low, middle and upper montane belts (500–1800 m. a.s.l.) of the greater and lesser Caucasus Mountains. Genetically it is differentiated from *P. pyraster* which is native to Eastern and Central European countries, the Balkan Peninsula and Turkey. However, both species show close genetic relations to domesticated pears (Asanidze *et al*. 2011).

Pyrus bretschneideri Rehd ('Xuehua pear' in Chinese) is a routine edible fruit that is also used as a folk medicine to treat cough, eliminate constipation, and relieve alcoholism. It is widely distributed in northern China. It is popular with consumers for its unique fragrance, desirable taste, sweetness and high digestibility (Xia *et al*. 2012).

Huanghua pears (*Pyrus pyrifolia* Nakai cv. 'Huanghua'), which are well known for their thin peel, delicate flesh, rich juice, and good taste, are one of the important fruits endemic to China. These are some main pear cultivars in Shanghai that are popularly known as Shanghaimi pears. These pears ripen at mid-summer (Zhou *et al*. 2011).

'Spadona' and 'Coscia' are the main pear cultivars grown in warm climates. Both of them are grafted on the same clonal quince A (EMA) (*Cydonia oblonga*) rootstock. Performance of 'Spadona' is satisfactory for tree vigor, cumulative yield and fruit quality and 'Coscia' suffers from poor vegetative growth, leading to a low yield of small fruit (Stern and Doron 2009).

Korla pear (*Pyrus bretschneideri* Rehd) is a native of the Xinjiang Autonomous Region in China. It is distinctive for its aroma, rich juicy flesh and crisp texture. However, it is more sensitive to mechanical injury than other fruits such as apple due to its higher water content (84.5-86%) and many stone cells are distributed in the flesh (Wu and Guo 2010).

Some *Pyrus* species were found to have different medicinal effects including anticancer, antiviral, laxative, anti-inflammatory, antipyretic, antimicrobial, antioxidant activity, and mild estrogenic activity. Chemically, *Pyrus calleryana* has been found to contain calleryanin, protocatechuoyl calleryanin, arbutin, *p*-hydroxybenzoic acid, in addition to alcoholic esters of caffeic, protocatechuic, *p*-hydroxybenzoic and vanillic acids, respectively with calleryanin. *P. calleryana* Decne is the main cultivated species in Egypt (Nassar *et al.* 2011).

The wild pear *Pyrus biossieriana* Buhse grows in northern Iran and Turkmenistan. The plants are medium-sized trees that can reach 5 m in height. The leaves are glossy green and oval. The pear leaves are useful for treatment of inflammation of the bladder, bacteriuria, high blood pressure and urinary stones; they also have diuretic properties. The leaves of this tree contain a considerable amount of arbutin (hydroquinone-β-D-glucopyranoside) (Shahaboddin *et al*. 2011). Although there are more than 2500 minor cultivars and 100 major ones, commercial pear production is limited to relatively few cultivars. In addition, the source of genetic diversity available for pear breeders is very large. Wild relatives of Iranian cultivated plants often have genes that can provide desirable qualities such as disease resistance, needed by plant breeders for crop improvement. A sound classification will be worthy of study in ecology, plant breeding, horticulture, and biochemistry (Kim *et al*. 2005).

'Khoj' is the local name of a kind of pear that widely grows in Guilan province in the north of Iran. Wild trees or shrubs of pears grow in the northern hemisphere from East to West. These pears belong to the Rosaceae family, Pomoidea subfamily, and *Pyrus* genus. Some 'Khoj' trees grow 20 m in height. In Iran, the wild types of 'Khoj' grow in different parts of the country (Sabety 2002; Mozaffarian 2004; Safarpur*et al*. 2008). It has spiny branches and buds with a smooth new shoot. Shiny-green leaves are almost round and oval in shape with a round base and crenate and serrate edge (Maniei 1992; Sabety 2002; Mozaffarian 2004). Flowers with white petals are 2.5 to 3 cm in length with a smooth or furry peduncle. Fruits of pome-type have various shapes from round to pear-shaped as well as the peel color of which varies from green to brown and even gray (Sabety 2002; Mozaffarian 2004).

According to Vavilov, the Russian botanist, there are three centers of diversity for pear as the origin including China, Central Asia and Caucasia mountains (Mitchell 1986), near the Caspian Sea, including in the north of Iran.

In Iran, the first study on pears was carried out to evaluate some internal and external traits of fruit in 1954 (Maniei 1992). Safarpur *et al*. (2008) reported that three Iranian native cultivars of *P. communis* probably originated from 'Khoj'. Moreover, there is no relationship between 'Khoj' and Asian pear. Mozaffari (2009) reported 28 varieties according to phenotypic traits from local varieties in Kurdistan province, West of Iran. Akbari and Sadat (2008) studied seed dormancy, chilling requirement, and germination of wild pear of Fars province, located in the center of Iran. They concluded that stratification for 60 days is the best treatment for removing seed dormancy.

Despite the vast diversity of 'Khoj' genotypes, little is known about them. Wild-type genotypes of the genus *Pyrus* are tolerant to a wide range of biotic and abiotic stresses such as drought and flooding, various soil texture, salinity and many fungal and bacterial diseases. Hence, they can be used as rootstocks and/or in breeding programs (Shibly *et al*. 1997; Kim *et al*. 2005). Identification and preservation of genetic resources based on vegetative and reproductive morphological traits and characteristics are considered as a basic step for future programs. This is the basis for this study.

MATERIALS AND METHODS

This research was performed in Fouman region, Guilan province, Iran, during the year 2009-2010. All the selected trees were grafted on seedling rootstocks. Winter and summer pruning were applied to all selected trees trained as multi leader branch. The local name of the genotypes used in this experiment included 'Latanz', 'Khalshekan', 'Amrud', 'Arbakhoj', 'Golabikhoj', 'Abkhoj', 'Rashthekhoj', 'Khojbabaei', 'Sangsar' and 'Zizaling'.

Based on the national guidelines for testing Distinctness, Uniformity and Stability (DUS) in accordance with the International Guidelines to Protect Plant Varieties (UPOV), traits were assessed. In this study 70 traits were investigated that 67 of them according to DUS guidelines, consisting of five traits related to the tree, nine related to branches, 13 traits describing leaf characteristics, 14 traits related to flowers, 28 characters related to fruits, and one attribute related to seed. Among these traits, three supplementary traits including the number of sepals and petals and the position of the ovary compared to other floral parts were added to the flower traits. Data regarding tree characteristics, vegetative and reproductive buds, leaves, flowers, and fruits was collected in March, April, and May. Finally, fruits were grouped into three classes of ripening time including early-season, from June to late July, mid-season from August to September, and late-season, i.e., November to late December during two consecutive years. Variance and cluster analyses were conducted using SAS software, version 9.1, and also mean comparison was accomplished using Duncan's multiple range test ($P \leq 0.05$).

RESULTS AND DISCUSSION

Tree characteristics

Among five assessed general traits of tree and trunk shapes, there were no lumps or bumps on the trunk. Growth vigor of 'Khalshekan', 'Golabikhoj', 'Khoj babaei' was the highest and 'Zizaling' and 'Arbakhoj', 'Abkhoj', 'Rashthekhoj',

Table 1 Comparison of tree and shoot traits of local pears based on DUS descriptor.

Genotypes	Vigor	Branching	Shoot color	Vegetative bud shape	Shoot size	Pubescence intensity
'Latanz'	Weak	Medium	brown	Obtuse	Medium	Weak
'Khalshekan'	Strong	Medium	Grey brown	Obtuse	Large	Absent
'Amrud'	Weak	Medium	Brown red	Obtuse	Large	Weak
'Arbakhoj'	Medium	Strong	Brown	Acute	Small	Weak
'Golabikhoj'	Strong	Strong	Grey	Acute	Small	Weak
'Abkhoj'	Medium	Strong	Brown	Obtuse	Medium	Weak
'Rashtehkhoj'	Medium	Strong	Brown	Obtuse	Medium	Weak
'Khoj babaei'	Strong	Strong	Brown red	Acute	Medium	Absent
'Sangsar'	Medium	Strong	Brown	Obtuse	Medium	Weak
'Zizaling'	Strong	Strong	Brown red	Obtuse	Large	Weak

Table 2 Botanical characteristics of local pears based on DUS descriptor.

Genotypes	L/W ratio	Basis	Apex	axis Curvature	Margin	Stipule
'Latanz'	1.45	right	right	weak	crenate	Absent
'Khalshekan'	1.15	obtuse	obtuse	weak	blunty serrate	Absent
'Amrud'	1.25	truncate	obtuse	weak	blunty serrate	Absent
'Arbakhoj'	1.23	truncate	right	weak	sharply serrate	Absent
'Golabikhoj'	1.16	cardiac	obtuse	weak	blunty serrate	Absent
'Abkhoj'	1.33	obtuse	right	weak	sharply serrate	Absent
'Rashtehkhoj'	1.16	truncate	obtuse	weak	sharply serrate	Absent
'Khoj babaei'	1.23	truncate	right	weak	sharply serrate	Absent
'Sangsar'	1.26	obtuse	obtuse	weak	sharply serrate	Absent
'Zizaling'	1.17	truncate	obtuse	weak	sharply serrate	Absent

'Sangsar' was medium; whereas 'Latanz' and 'Amrud' had low growth vigor. 'Latanz' growth habit and canopy shape were erect, while 'Golabikhoj', 'Abkhoj', 'Rashtehkhoj', 'Khojbabaei', and 'Zizaling' were semi-erect; however, 'Khalshekan', 'Amrud', 'Arbakhoj', and 'Sangsar' were spread type. Branch bearing was moderate in 'Latanz', 'Khalshekan', 'Amrud', and 'Sangsar'; while, it was high in other genotypes (**Table 1**). The situation of trunk bark in pear tree might be smooth, veiny, or scaling which were observed in the genotypes studied here. Common characteristics of trees might considerably be affected by environmental factors and agricultural operations. Hence, they cannot be considered as indicators of digits (Tahzibihagh *et al*. 2009). Among the five attributes of the tree, the scale of branch bearing is an important characteristic for morphological studies.

Annual branching

Among the nine evaluated traits related to offshoot and annual branches in Khoj genotypes, there were no significant differences in terms of annual growth of branches. 'Khalshekan' and 'Rashtehkhoj' had the smallest and the largest internodes, respectively. Lenticels number ranged from low, in 'Khalshekan' and 'Golabikhoj' too high in 'Arbakhoj' and 'Khojbabaei'; and the remaining genotypes were moderate. According to the results, among the 4 key characteristics- based on distinction, uniformity and stability exams, the situation of diversity of vegetative bud on branch and anthocyanin pigment was high and the diversity of bud tip shape and hair density of young branch was low. In 'Golabikhoj', the same side of annual branch which faces the sun was gray, while in the other genotypes vary from brown to pale brown, grayish brown and red. The shape of tip of the terminal buds on the pear trees might be round, sharp, and slow that in the investigation of genotypes only two cases of slow and sharp tip were observed. Terminal bud tip in 'Golabikhoj', 'Arbakhoj', and 'Khojbabaei', was sharp, but in the other genotypes it was slow (**Table 2**). Anthocyanin pigment in the tips of current shoots of 'Khalshekan' and 'Sangsar' was trace; in 'Latanz', 'Arbakhoj', 'Golabikhoj' and 'Zizaling', it was moderate, and it was high in the remaining four genotypes. The hair density in the upper third of the young shoots was low in all studied genotypes. According to Asannidze *et al.* (2011), taxonomical classifications of pears are built mainly on shape, size and characters of leaves, shoots and fruits, as well as presence of thorns on young shoots.

Leaf characteristics

Among the 13 traits related to leaf, the studied genotypes did not show any variation in leaf conditions related to branch, surge in axis, stipule and its distance from the leaf base. There was significant variation in lamina length and width and their ratio, shape of the lamina base and leaf end, length of leaf tip, and sharp cutting edges of the leaves (**Table 2**). Maximum and minimum length of the lamina were observed in 'Rashtehkhoj' and 'Latanz, respectively. The highest ratio of length to width (1.45) was observed in 'Latanz' while the lowest ratio was observed in 'Khalshekan' (1.15). According to DUS, the type of leaf shape was sharp, straight, open, and heart-shaped and the shape of the leaf end in the evaluated genotypes included sharp, straight, open, or round. The depth of cut leaf margins varied from less to medium in all genotypes. No stipules were observed in the studied genotypes. The leaf characteristics were regarded as the most important taxonomic traits; however, leaf traits alone were insufficient for a taxonomic classification of *Pyrus*. Therefore, fruit traits were considered in addition as very useful tree characteristics for identification purposes (Asannidze *et al*. 2011).

Reproductive traits (flowers)

The place where flower buds formed was on the spurs in all studied genotypes. Therefore, genotypes had no differences in this trait. According to the time of anthesis, 'Zizaling' blooms early, while 'Amrud' and 'Abkhoj' bloom late, and the other genotypes are so (not early and late). Pear flowers are complete and appear simultaneously with leaves. Their flowering period lasted between 12 and 16 days. The pollination period took 1-5 days according to climate and tree physiological conditions. When comparing the calyx and corolla, three attachment forms were observed: spreading, re-curved and attached (**Table 3**). The number of petals and sepals and ovary position related to other parts of flower was determined in all genotypes, which had five sepals and five petals, except for 'Latanz' which had ten petals. The ovary was lower than other parts. There were some differences in floral components (**Fig. 1**). Increasing flower parts, such as petals and sepals in some pears cultivar, causes increased fruit size (Mozaffari 2009).

Table 3 Comparison of some flower organ traits of local pears based on DUS descriptor.

Genotypes	Calyx/corolla	Petal position	Petal size	Petal shape	Petal base shape	Stigma/stamen
'Latanz'	Attached	Overlapping	Small	Ovate	Cuneal	Upper
'Khalshekan'	Attached	Overlapping	Large	Circular	Cuneal	Upper
'Amrud'	Attached	Apart	Medium	Circular	Cuneal	Under
'Arbakhoj'	Attached	Tangent	Small	Circular	Cuneal	Upper
'Golabikhoj'	Attached	Tangent	Small	Circular	Cuneal	Equal
'Abkhoj'	Attached	Tangent	Medium	Circular	Cuneal	Upper
'Rashtehkhoj'	Attached	Apart	Small	Circular	Cuneal	Upper
'Khoj babaei'	Attached	Tangent	Large	Ovate	Cuneal	Upper
'Sangsar'	Attached	Overlapping	Medium	Circular	Cuneal	Equal
'Zizaling'	Attached	Apart	Medium	Circular	Cuneal	Equal

Table 4 Comparison of some fruit traits of local pears based on DUS descriptor.

Genotypes	Maximum diameter	Size	Symmetry	Profile sides	Hue of over color	Attitude of sepals	Pulp juiciness
'Latanz'	Clearly towards calyx	Very large	Completely asymmetric	Concave	Green yellow	Spreading	Medium to dry
'Khalshekan'	Clearly towards calyx	Large	Symmetric	Convex	Yellow green	Converging	Juicy
'Amrud'	middle	Large	Slightly asymmetric	Convex	Yellow green	Converging	Medium
'Arbakhoj'	middle	Small	Symmetric	Convex	Brown	Erect	Juicy
'Golabikhoj'	Slightly towards calyx	Medium	Symmetric	Convex	Green	Converging	Medium
'Abkhoj'	middle	Large	Slightly asymmetric	Convex	Brown	Converging	Very juicy
'Rashtehkhoj'	Slightly towards calyx	Large	Symmetric	Straight	Brown	Spreading	Medium
'Khoj babaei'	In middle	Large	Slightly asymmetric	Convex	Brown	Erect	Juicy
'Sangsar'	middle	Very large	Slightly asymmetric	Convex	Brown	Erect	Juicy
'Zizaling'	middle	Small	Symmetric	Convex	Gray	Erect	Medium

Fruit traits

'Latanz' genotype had the largest fruit while 'Arbakhoj' produced the smallest. 'Sangsar' and 'Arbakhoj' had the most and least fruit diameter, respectively. Position of maximum diameter in 'Latanz', 'Khalshekan', 'Golabikhoj' and 'Rashtehkhoj' was clearly towards the calyx and the other genotypes it was in the middle of the fruit (**Table 4**). Symmetry properties in longitudinal section differed for different genotypes. Thus, 'Latanz' was completely asymmetrical and 'Amrud', 'Abkhoj', 'Khoj Babaei' and 'Sangsar' were slightly asymmetric while in other genotypes symmetry was observed. Sepal mode was spreading in the fruit at harvest time in 'Latanz' and 'Rashtehkhoj', erect in 'Khalshekan', 'Amrud', 'Golabikhoj' and' Abkhoj', and converging in other genotypes (**Table 4**). Russeting, which causes a mottled brown appearance on the pears but does not harm the eating quality, in different parts of fruits varied in the genotypes. Lowest russeting was observed in 'Amrud'. Severity of russeting and its distribution on the fruit surface is a genetic characteristic of the cultivar; however, it could be affected by climatic factors such as humidity. Typically, if humidity increases during fruit growth, the russeting rate will increase in pear cultivars (Tahzibihagh *et al*. 2010). According to adequate moisture in the weather of Guilan province and also genetic characteristics of local pear fruits, the amount of russeting in this genotype was higher than in other genotypes. 'Latanz' had the largest fruits and was the earliest to ripen while 'Zizaling' had the latest-season fruit (**Fig. 2**).

Cluster classification of genotypes

The studied genotypes were analyzed regarding to the length and diameter of fruits, their ratio and fruit weight. 'Latanz', 'Abkhoj' and Sangsar' with largest fruits were grouped into the first cluster, 'Khalshekan', 'Amrud', 'Rashtehkhoj', 'Khojbabaei' with medium size fruits were placed in the second cluster while 'Arbakhoj', 'Golabikhoj' and 'Zizaling' with small-sized and lower weight fruits were grouped into the third cluster (**Fig. 3**).

CONCLUSION

DUS is applicable for distinguishing wild pears growing in northern Iran. Analysis of botanical and pomological traits

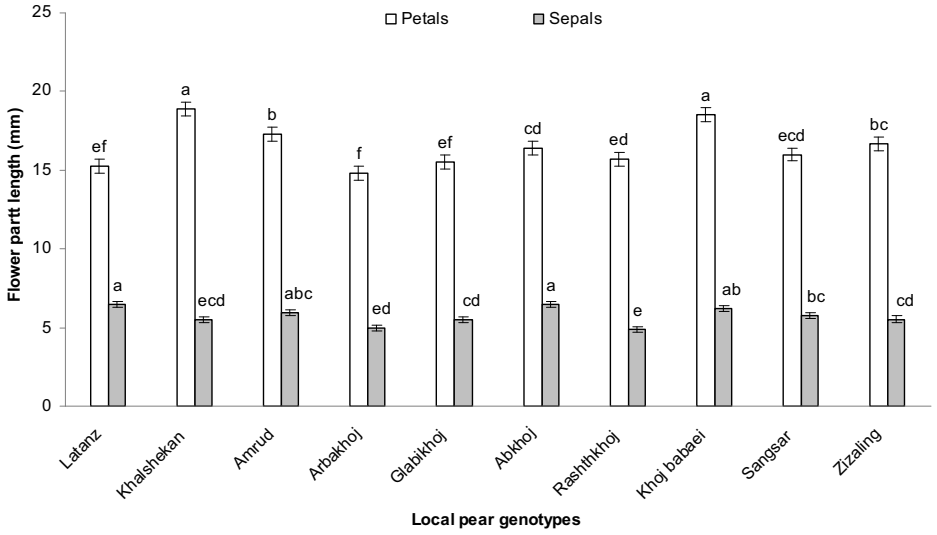

Fig. 1 Petal and sepal length in selected local pears. Vertical bars indicate SEm. Different letters above petal or sepal bars indicate significant differences ($P \leq 0.05$, DMRT; n=5).

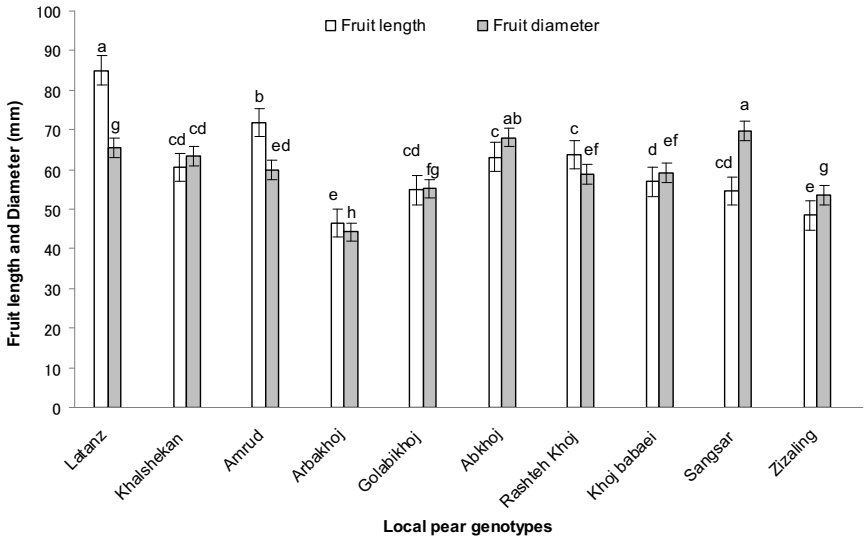

Fig. 2 Fruit length and diameter of selected local pears. Vertical bars indicate SEm. Different letters above petal or sepal bars indicate significant differences ($P \leq 0.05$, DMRT; n=5).

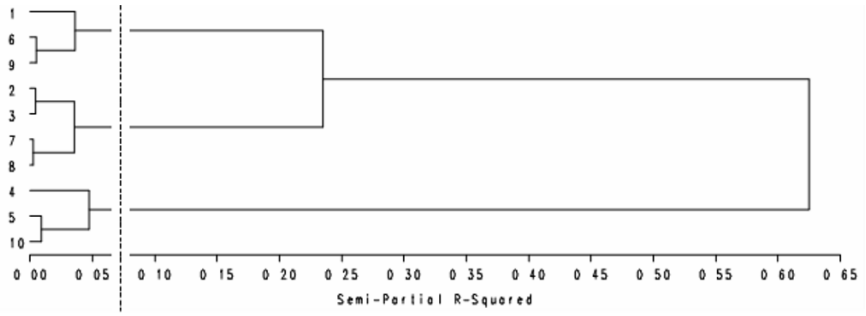

Fig. 3 Dendrogram of the local pears classified based on fruit length, diameter and weight. Genotype number corresponds to genotype listing in tables.

revealed that select genotypes had a wide variety and were categorized into separate groups. Early flowering is not necessarily related to early fruit ripening.

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REFERENCES

Akbari M, Seadat YZ (2009) Breaking the recession and seed germination of wild pear (*Pyrus* spp.). *Journal of Research and Genetically Modified Plants for Forestry Iran* **14 (2)**, 92-104

Asanidzea Z, Akhalkatsia M, Gvritishvili M (2011) Comparative morphometric study and relationships between the Caucasian species of wild pear (*Pyrus* spp.) and local cultivars in Georgia. *Flora* **206**, 974-986

Bao L, Chen K, Zhang D, Li X, Tenga Y (2008) An assessment of genetic variability and relationships within Asian pears based on AFLP (amplified fragment length polymorphism) markers. *Scientia Horticulturae* **116**, 374-380

Brinia W, Mars M, Hormazab JI (2008) Genetic diversity in local Tunisian pears (*Pyrus communis* L.) studied with SSR markers. *Scientia Horticulturae* **115**, 337-341

Jalili MR (2009) *Fruit in Temperate Zones*, Uromia University Press, Iran, 362 pp

Kim CS, Lee CH, Park KW, Kang SJ, Shin IS, Lee GP (2005) Phylogenetic relationships among *Pyrus pyrifolia* and *P. communis* detected by randomly amplified polymorphic DNA (RAPD) and conserved rDNA sequences. *Scientia Horticulturae* **106**, 491-501

Li X, Zhang J, Gao W, Wang H (2012) Study on chemical composition, anti-inflammatory and anti-microbial activities of extracts from Chinese pear fruit (*Pyrus bretschneideri* Rehd.). *Food and Chemical Toxicology* **50**, 3673-3679

Maniei A (1994) *Training Pear and Quince Trees*, Iran Technical Publishing Co., Tehran, 104 pp

Mitchell PD (1986) Pear fruit growth and the use of diameter to estimate fruit volume and weight. *Horticultural Science* **21**, 1003-1005

Mozafari A (2009) Identification of pear cultivars native to central and western parts of Kurdistan (Iran). *Journal of Agricultural Science* **32 (1)**, 39-51

Mozafarian V (2004) *Trees and Shrubs of Iran* (2nd Edn), Publications of Farhang Moaser (Iran), 991 pp

Nassar M, Mohmed T, El-Toumy S, Gaara A, Kashak W, Brouard I, El-Kousy S (2001) Phenolic metabolites from *Pyrus calleryana* and evaluation of its free radical scavenging activity. *Carbohydrate Research* **346**, 64-67

Pierantoni L, Dondini L, De franceschi P, Musacchi S, Winkel B, Sansavini S (2010) Mapping of an anthocyanin-regulating MYB transcription factor and its expression in red and green pear, *Pyrus communis*. *Plant Physiology and Biochemistry* **48**, 1020-1026

Sabety H (2002) *Trees and Shrubs of Iran*, Tehran University Press, 810 pp

Safarpor M, Bahar M, Ebrahim Seiidtabatabei B, Abdolahi H (2008) The genetic diversity of cultivars of pear (*Pyrus* spp.) using microsatellite markers. *Journal of Horticultural Science and Technology of Iran* **9 (2)**, 113-128

Sakamoto D, Hayama H, Ito A, Kashimura Y, Moriguchi T, Nakamura Y (2009) Spray pollination as a labor-saving pollination system in Japanese pear (*Pyrus pyrifolia* (Burm. f.) Nakai): Development of the suspension medium. *Scientia Horticulturae* **119**, 280-285

Shahaboddin M, Pouramir M, Moghadamnia A, Parsian H, Lakzaei M, Mir H (2011) *Pyrus biossieriana* Buhse leaf extract: An antioxidant, anti-hyperglycaemic and antihyperlipidemic agent. *Food Chemistry* **126**, 1730-1733

Sharifani M, Bagerian A, Nishtani C, Kimura T (2008) Mutation in chloroplast DNA revealed relation and discrimination in genus *Pyrus*. *Acta Horticulturae* **800**, 355-363

Shibli RA, Ajlouni MM, Jaradat A, Aljanabi S, Shatnaw M (1997) Micropropagation in wild pear (*Pyrus syrica*). *Scientia Horticulturae* **68**, 237-242

Soltani A (2007) *SAS Statistical Software Used in the Analysis*, Mashhad University Press, 182 pp

Stern R, Doron I (2009) Performance of 'Coscia' pear (*Pyrus communis*) on nine rootstocks in the north of Israel. *Scientia Horticulturae* **119**, 252-256

Tahzibihagh F, Abdolahi H, Ghasemi A, Fathi D (2009) Vegetative and reproductive traits of some Iranian native pear (*Pyrus communis* L.) cultivars in climatical conditions of Karaj (Iran). *Journal of Plant Breeding and Seed* **27 (1)**, 37-55

Wu J, Guo K (2010) Dynamic viscoelastic behaviour and microstructural changes of Korla pear (*Pyrus bretschneideri* Rehd) under varying turgor levels. *Biosystems Engineering* **106**, 485-492

Zhou R, Li Y, Yan L, Xie J (2011) Effect of edible coatings on enzymes, cell-membrane integrity, and cell-wall constituents in relation to brittleness and firmness of Huanghua pears (*Pyrus pyrifolia* Nakai, cv. Huanghua) during storage. *Food Chemistry* **124**, 569-575