Indian Journal of Agricultural Sciences **83** (2): 150–8, February 2013/Article

Multivariate analysis of phenological, pomological and fruit quality characters in apricot (*Prunus armeniaca*) grown in trans-Himalayan Ladakh region, India

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Received: 23 November 2011; Revised accepted: 25 December 2012

ABSTRACT

The purpose of this study was to contribute to the phenological, pomological characteristics and fruit quality specification of 17 apricot genotypes grown under similar cultural practices in trans-Himalayan Ladakh region. A total of 27 characters were analyzed during the two years of study course. A wide variation in bud break season, blossom season, harvest season, fruit size, stone mass, TSS and total acidity was observed. Except for one genotype, fruit weight from all other genotypes were determined ≤35.1 g, which shows that apricot fruit of Ladakh region are mainly composed of low fruit weight genotypes. All the evaluated genotypes showed high TSS content ranging from 16.1-20.6%. Significant correlation within the pomological and phenological characteristics was observed. The correlation between fruit development period and fruit weight is low, indicating that fruit size is not simply determined by the number of days from end of blossoming to fruit harvest period. Eigenvectors resulting from Principal Component Analysis show that more than 57% of the variation is explained by the first three principal components (PC1-PC3).

Key words: Apricot, Ladakh, phenology, pomology, *Prunus*, Trans-Himalaya

Fruits of the apricot (*Prunus armeniaca* L.) are commonly consumed in many parts of the world and constitute a vital component of the diet. Apricot is mostly grown in Turkey, Iran, Pakistan, Uzbekistan and Italy. In India apricot is grown on 2400 hectare and the estimated annual production is 10 000 tonnes in 2008 (faostat.fao.org).

Most of cultivated apricot varieties today have come from random selection (Audergon 2005). Therefore study of native genotypes in terms of fruit quality, late flowering habit, extended ripening season, local adaptation have been considered both for selection of varieties as well as for breeding efforts for apricot. There have been many studies concerning the germplasm resources of European (Audergon *et al*. 1991, Badenes *et al*. 1998, Guerriero *et al*. 1995) and Irano-Caucasian ecogeographical group (Asma and Ozturk 2005, Asma *et al*. 2007, Gulcan 1988). However, the number of reports on Trans-Himalayan germplasm is limited (Dwivedi *et al*. 2002). Accordingly, the purpose of this study was to contribute to the phenological, pomological characteristics and fruit quality specification of selected apricot genotypes on the basis of two year observations and to determine correlations among variables and establish relationship among genotypes with the help of multivariate analytical approach.

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MATERIALS AND METHODS

Seventeen apricot genotypes were used in this work. All genotypes were grafted on Chuli wild apricot rootstock in 1998 and planted in orchard in 2000. The selection of the genotypes was based on their importance in the region and differences in pomological traits. Safeda, Afghani and Charmagz are introduced cultivars while the rest are native genotypes of Ladakh region.

The study was carried out in 2009 and 2010 at an experimental orchard of Defence Institute of High Altitude Research located at latitude 34°08.2'N, longitude 77°34.3'E, altitude 3340 m in Trans-Himalayan region. Altitude and location of the orchard was established using GARMIN *GPS 72*, USA. The orchard contains 12 rows, 8 trees per row. Trees were trained to the modified central leader system and planted at a spacing of 4 m × 4 m. All trees were of the same age and standard cultural practices were performed. The soil texture of the orchard is silty loam with pH 6.8±0.3. Organic carbon and organic matter content is 0.67±0.3% and 1.16±0.5%, respectively. The soil colour in terms of L* - lightness, a – redness, b – yellowness is 23.5±3.6, 8.9±0.7 and 3.5±3.0, respectively. The mean maximum and minimum

temperature in the experimental locality is 18.9ºC and 5.8ºC, respectively during the last decade. Average annual precipitation is less than 200 mm of which more than 70% is in the form of snowfall.

A total of 27 characters were analyzed. Phenological characters analyzed include bud break season, blossom season, end of blossoming, harvest season, period of fruit development and leaf fall season. Fruit qualitative character such as fruit shape, ground colour of fruit skin, blushing of fruit skin, flesh colour, degree of flesh hollowness, stone shape and stone adherence were determined. The fruit quantitative traits such as fruit weight, dimension, flesh width, and percent pulp in fruit were determined at the time of harvest. Standard quality parameters such as total soluble solids (TSS), titrable acidity (TA), pH and TSS/TA of fruits were determined after harvest. Total soluble solids were measured with refractometer (ATAGO, Tokyo) and values were corrected at 20ºC. TA was determined by titration using 0.1N NaOH and values expressed as % mallic acid (Rangana 1986).

The 13 phenological and qualitative characters that we measured or classified in this study are based on recommended plant descriptors for apricot proposed by International Bureau of Plant Genetic Resources (IBPGR) (Guerriero and Watkins 1984) and National Institute of Agrobiological Sciences (NIAS) Genebank, Japan. Scoring of bud break season, blossom season and harvest season are based on classification reported by Asma and Ozturk (2005), while scoring of end of blossoming is proposed in this study. Dimensional properties were measured by a digimatic calliper (CD-6"CS, Mitutoya, Japan) to an accuracy of 0.01 mm. The weight of fruit and stone were measured by an electronic balance to an accuracy of 0.001 g. Colour attributes of apricot pulp were measured using a colour comparison device (PocketSpec ColorQA, Colorado). Results originally in RGB colour scale, were expressed as L* -lightness, a – redness, b – yellowness using a web-based software (www.easyrbg.com). The lists of descriptors utilized for phenological variability evaluation of apricot genotypes are listed in Table 1.

As a tool for germplasm description, we have used principal component analysis (PCA) to study correlations among variables and established relationship among cultivars. This method is commonly applied for characterization of genetic resources in such studies (Asma and Ozturk 2005, Badenes *et al*. 1988, Hilling and Iezzoni 1988, Perez-Gonzales 1992). One way ANOVA by Duncan multiple range test and Bivariate Pearson correlation using SPSS 11.5 version for window. For multivariate analysis, a similarity matrix was created first by using Gower's (1971) general coefficient similarity (Sneath and Sokal 1973) with the help of MVSP ver. 3.2, which can be used directly with a mixture of character types as well as taking into account missing values. This similarity matrix was then clustered by using UPGMA and the results are showed in the phenogram.

RESULTS AND DISCUSSION

Phenological, pomological and fruit quality traits

The genotypes bud broke between 25 February to 19

Table 1 Scoring of phenological characteristics of 17 apricot genotypes of trans-Himalayan Ladakh region

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Bud break season	1	3	2	2	2	2	2	1	2	3	3	1	1	3	3	1	3
Blossom season	2	3	3	3	3	4	3	2	3	3	3	1	2	4	4	1	4
End of blooming	4	4	5	5	5	5	4	4	3	5	5	3	4	5	5	1	5
Harvest season	3	3	5	6	6	5	5	5	3	6	5	1	5	5	5	3	5
Fruit development period	1	2	2	2	2	2	3	3	2	3	2	1	3	2	2	2	2
Leaf fall season	1	2	2	3	3	2	2	2	3	2	2	1	2	2	3	2	3
Fruit shape	2	1	1	1	1	1	2	1	1	1	1	1	2	2	1	2	1
Ground colour of fruit skin	5	1	6	6	5	6	4	1	5	7	4	5	1	4	7	1	7
Blushing of fruit skin	5	1	0	1	0	0	0	1	1	4	0	5	2	1	1	1	1
Flesh colour	5	5	5	6	6	6	7	5	5	7	5	5	5	5	7	5	6
Acidity of juice	3	3	3	3	3	5	5	3	3	3	3	3	3	3	3	3	3
Degree of flesh hollowness	1	1	1	3	3	3	1	1	1	1	1	1	3	1	1	3	1
Stone size	3	1	1	1	1	1	1	3	1	1	1	1	1	1	1	1	1
Stone shape	3	1	4	1	3	1	4	3	4	3	3	3	2	2	3	3	3
Stone adherence	5	5	7	5	7	5	5	7	5	7	7	3	7	5	7	5	7
Stone surface	1	1	1	1	2	2	2	1	2	1	1	1	1	1	1	1	1
Kernel taste	2	3	1	1	3	1	1	1	3	1	1	3	1	1	1	1	1

1. Safeda, 2. Selection-73, 3. Turtuk CP-3, 4. Hanu Selection-3, 5. Garkhond Selection-1, 6. Hanu Selection-5, 7. Selection-21, 8. Tokpopa, 9. Saspol Selection-3, 10. Turtuk CP-2, 11. Selection-13. 12. Achinathang 5, 13. Afghani, 14. Charmagz, 15. Raktsey Karpo, 16. Halman, 17. Raktsey Karpo Chenmo

March in 2009 and 3-30 March in 2010. The time of blossoming occurred between 8 March to 6 April in 2009 and 17 March to 19 April in 2010. A 29-33 days variation between the genotypes in blossom season was observed during the two years of study course. Late blossoming is an important factor to protect any damage caused by spring frost and therefore a desirable trait in region experiencing spring frost. End of blossoming in 2009 was between 10-28 April while the same occurred between 16 April to 8 May in 2010. There are large variations in harvest season between genotypes. Achinathang-5 is the earliest ripening genotype which attended physiological maturity on 28 June in 2009 and 10 July in 2010. On contrast, Turtuk CP-2 genotype attended maturity on 6 August in 2009 and 10 August in 2010. With exception of few, most of the genotypes were harvested at late July. In comparison apricot in Anotolia, Turkey are harvested in late June and early July (Asma and Ozturk 2005) while those from lake Van Region, Turkey are harvested in late July to early August (Balta *et al*. 2002). The difference in harvest season between the earliest and the late genotypes was 31-39 days. Similar results was observed in majority of cultivars in Malatya, Turkey (Asma *et al*. 2007). In contrast, only 14-15 days difference in harvest season was reported for 15 apricot genotypes grown in Central Serbia (Miloševic *et al*. 2010). Harvesting spanning more than one month in a year is an important element in view of short shelf life of fresh apricot fruit. The period of fruit development (blossom season-harvest) differed depending on the genotype and year. It ranged from 86-108 days in 2009 and 85-101 days in 2010. In both the year, the shortest period was recorded in Safeda genotype while Turtuk CP-2 had the longest fruit development period.

Table 2 presents pomological and fruit quality characteristics for 17 apricot genotypes. With regards to fruit dimensions, there were large variations between fruit weight in all the genotypes studied. Except for Raktsey Karpo Chenmo genotype fruit that weight 43.2 g, fruit weight from all other genotypes were determined ≤35.1 g. In a similar study, the fruit weight among the promising genotypes of the Lake Van region ranged from 24.2-48.3 g (Balta *et al*. 2002). In contrast Miloševic *et al*. (2010) reported fruit weight of 49.1-81.5 g in promising apricot resources in Central Serbia. The fruit weight of 21 apricot cultivars collected from Czech Republic, Ukraine, Canada and USA ranged between 28.1-77.7 g with mean weight of 42.44 g (Vechùn 2003). The difference between our results and those of Balta *et al*. (2002), Miloševic *et al*. (2010) and Vechùn (2003) could be due to the different ecogeographical group of apricot cultivar studied. Similarly, wide variation was recorded in mean fruit length, diameter, thickness and flesh width ranging from 29.2-44.8, 30.0-44.4, 27.2-44.8 and 4.5-13.1 mm, respectively. This shows that apricot fruit of Ladakh region are mainly composed of low fruit weight genotypes.

All the evaluated genotypes showed high TSS content ranging from 16.1-20.6%. The value ranged from 11-26.5ºBrix among 128 apricot cultivars and types in Malatya, Turkey and 15.7-18.9% in 14 genotypes grown in Central Serbia (Asma and Ozturk 2005, Miloševic *et al*. 2010). The acidity was between 0.5-2.6%, and lower than 1% mallic acid in nine genotypes. Colour of fruit pulp in terms of lightness (L*), redness (a) and yellowness (b) ranged from 12.8-28.4, 2.8-7.7 and 7.6-15.5, respectively. The mean stone weight of the selected genotypes in 2009–10 ranged from 1.7-3.5 g which is similar to results reported by Asma and Ozturk (2005) for apricot genotypes in Turkey. However, the values are much lower as compared to 2.98-5.01 g reported by Miloševic *et al*. (2010) in promising apricot genetic resources in Central Serbia. Eventhough fruit qualitative characters were influenced by the year to a certain extent, the genotypes maintained a higher or a lower point value of the trait in a period of evaluation. Majority of the genotypes studied had sweet kernel which is similar to the results of apricot genotypes in Malatya, Turkey (Asma and Ozturk 2005).

Correlation among variables

Table 3 present correlations between characters that showed *r* value of more than 0.6 with at least one another characters. Phenological characteristics are significantly correlated. The highest correlations were those of bud break and blossom season (r = 0.81), blossom season and end of blossom (r = 0.76), harvest season and end of blossoming (r = 0.71), harvest season and stone adherence character (r = 0.71). Significant negative correlation (r = –0.70) between harvest season and pulp lightness colour (L*) was observed. High correlation between bud break and blossom season is in agreement with results of Badenes *et al*. (1998) while Asma and Ozturk (2005) found no such correlation. Correlation between bud break and harvest season was not significant (r = 0.41). Badenes *et al*. (1998) found significant correlation (r = 0.79) while Asma and Ozturk (2005) reported non-significant correlation (r = –0.003) between the two phenological characters. The correlation between fruit development period and fruit weight is low (r = 0.02), indicating that fruit size is not simply determined by the number of days from end of blossoming to fruit harvest period.

The pomological characteristics of genotypes studied were highly correlated. Fruit weight, length, diameter, width and pulp (%) are significantly correlated (r = >0.75). Stone weight is significantly correlated with fruit weight (r = 0.89). Therefore, fruit with larger size have larger pulp (%) and seed weight. There was no direct correlation between fruit weight and TSS and also acidity level. The results are in agreement with the reports of Asma and Ozturk (2005).

Principal component analysis

Eigenvectors resulting from PCAs show that more than 57% of the variation is explained by the first three principal

Table 2 Pomological and fruit quality characteristics of apricot genotypes of trans-Himalayan Ladakh region

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Fruit wt (g)	2009	24.3	34	32.5	15.3	24.1	16.7	13.0^{ab}	35.5	11.9	14.6	18.6	18.5	26.3	14.6	18.7	13	42.6
		±1.8^{e}	±4.7^{fg}	±3.9^{f}	±0.7^{bc}	±2.2^{e}	±1.4^{cd}	±0.9	±3.0^{g}	±0.8^{a}	±1.7^{bc}	±1.4^{d}	±1.5^{d}	±1.5^{e}	±2.7^{bc}	±1.4^{d}	±0.9^{ab}	±4.4^{h}
	2010	25.2	32.2	32.9	18	23.5	17.4	13.8	34.7	12.7	15.5	19.5	19.2	25.3	14.9	19.2	13.9	43.8
		±1.4^{d}	±10.2^{e}	±3.8^{e}	±6.2^{bc}	±2.0^{d}	±1.4^{bc}	±1.0^{a}	±2.8^{e}	±1.1^{a}	±2.0^{ab}	±1.6^{c}	±1.3^{c}	±1.8^{d}	±2.4^{ab}	±1.6^{c}	±1.2^{a}	±4.8^{f}
	Mean	24.8	33.1	32.7	16.7	23.8	17.1	13.4	35.1	12.3	15.1	19.1	18.9	25.8	14.8	19	13.5	43.2
		±0.6^{fg}	±1.3^{h}	±0.3^{h}	±1.9^{cd}	±0.4^{f}	±0.5^{d}	±0.6^{ab}	±0.6^{i}	±0.6^{a}	±0.6^{bc}	±0.6^{e}	±0.5^{e}	±0.7^{g}	±0.2^{b}	±0.4^{e}	±0.6^{ab}	±0.8^{j}
Fruit length (mm)	2009	38.4	40.2	44.3	33.4	35.2	34.7	28.7	44.3	29.9	31.3	34.7	36.4	39.5	31.9	35.7	28.7	44.3
		±1.4^{f}	± 2.0^{g}	±1.7^{h}	±1.1^{d}	±1.5^{e}	±1.5^{de}	±0.9^{a}	±1.3^{h}	±1.3^{ab}	±1.3^{bc}	±3.6^{de}	±1.5^{e}	±0.9^{fg}	±2.4^{c}	±1.1^{e}	±0.9^{a}	±2.5^{h}
	2010	39.4	41.3	45.2	34.3	36.2	36	29.6	45.1	31.1	32	35.6	37.2	40.5	32.8	36.7	29.6	45.2
		±1.0^{g}	±2.2^{h}	±1.7^{i}	±1.0^{de}	±1.8^{f}	±1.7^{f}	±1.1^{a}	±1.4^{i}	±1.7^{ab}	±1.5^{bc}	±3.5^{ef}	±1.2^{f}	±1.1^{gh}	±2.6^{cd}	±1.4^{f}	±1.0^{a}	±2.3^{i}
	Mean	38.9	40.8	44.8	33.9	35.7	35.4	29.2	44.7	30.5	31.7	35.2	36.8	40	32.4	36.2	29.2	44.8
		±0.7^{g}	±0.8^{h}	±0.6^{i}	±0.6^{d}	±0.7^{ef}	±0.9^{def}	±0.6^{a}	±0.6^{i}	±0.8^{ab}	±0.5^{bc}	±0.6^{de}	±0.6^{f}	±0.7^{gh}	±0.6^{c}	±0.7^{ef}	±0.6^{a}	±0.6^{i}
Fruit dia (mm)	2009	36	39.8	37.5	32	37	32.3	30.7	40.6	29.7	31.8	34.1	33.5	37.1	31.1	34.2	30.7	44
		± 1.1^{f}	± 2.1^{h}	± 2.7^{g}	±0.7^{bcd}	± 1.6^{fg}	± 1.4^{cd}	± 0.7^{ab}	± 1.3^{h}	± 0.8^{a}	± 0.9^{bc}	± 1.4^{e}	±1.2^{de}	±1.1^{fg}	± 2.5^{bc}	± 1.2^{e}	±0.7^{ab}	± 2.3^{i}
	2010	37.1	41.1	38.3	33.4	38.1	33.3	31.4	41.4	30.3	32.6	34.5	34.3	38	31.6	35.1	31.4	44.8
		±1.1^{f}	±2.1^{g}	±2.2^{f}	±1.2^{cd}	±1.4^{f}	±1.7^{cd}	±1.0^{ab}	±1.0^{g}	±1.3^{a}	±0.8^{bc}	±1.4^{de}	±1.6^{de}	±1.1^{f}	±2.8^{ab}	±1.5^{e}	±1.1^{ab}	±2.2^{h}
	Mean	36.55	40.5	37.9	32.8	37.6	32.8	31.1	41	30	32.2	34.3	33.9	37.6	31.4	34.7	31.1	44.4
		±0.8^{f}	±0.9^{g}	±0.6^{f}	±0.9^{cd}	±0.8^{f}	±0.7^{cd}	±0.5^{bc}	±0.6^{g}	±0.4^{a}	±0.6^{bc}	±0.3^{e}	±0.6^{de}	±0.6^{f}	±0.4^{bc}	±0.6^{e}	±0.5^{bc}	±0.6^{h}
Fruit thickness (mm)	2009	34.5	36.3	33.6	33.1	34.5	38.2	30.6	28.3	28.6	30.7	32.9	33.5	33.5	35.7	37.1	35.1	43.7
		±1.1^{cde}	±0.6^{fg}	±0.6^{cd}	±0.7^{c}	±0.6^{cde}	±0.9^{h}	±0.5^{b}	±1.0^{a}	±0.7^{a}	±0.5^{b}	±0.4^{c}	±1.5^{cd}	±0.6^{cd}	±1.1^{efg}	±1.8^{gh}	±0.7^{def}	±1.4^{i}
	2010	36.4	34.4	31.7	35	32.8	40	32.3	26.1	30.5	32.4	35.1	35.3	31.9	37.9	38.9	36.7	45.9
		±1.3^{efg}	±1.2^{de}	±0.1^{bc}	±0.4^{ef}	±0.9^{d}	±0.9^{i}	±0.6^{bc}	±0.9^{a}	±0.7^{b}	±0.8^{bc}	±0.6^{ef}	±2.0^{ef}	±1.0^{bc}	±1.3^{gh}	±2.2^{hi}	±0.2^{fg}	±1.5^{j}
	Mean	35.4	35.4	32.7	34.1	33.7	39.1	31.5	27.2	29.6	31.6	34	34.4	32.7	36.8	38	35.9	44.8
		±1.3^{defg}	±1.3^{defg}	±1.3^{cd}	±1.3^{cdef}	±1.2^{cdef}	±1.3^{h}	±1.2^{bc}	±1.6^{a}	±1.3^{ab}	±1.2^{bc}	±1.6^{cdef}	±1.3^{cdef}	±1.1^{cde}	±1.6^{fgh}	±1.3^{gh}	±1.1^{efg}	±1.6^{i}
Fruit flesh width(mm)	2009	10.3	12.8	11.8	7.5	10.3	8	7	12.5	7.1	7.1	8.2	4	9.3	7.3	8.2	7	12.7
		± 0.7^{f}	±1.3^{h}	±0.8^{g}	±0.4^{bcd}	±0.3^{f}	±0.4^{cd}	±0.4^{b}	±0.6^{gh}	±0.2^{b}	±0.4^{b}	±0.5^{d}	±2.8^{a}	±0.2^{e}	±0.1^{bc}	±0.5^{d}	±0.4^{b}	±0.5^{h}
	2010	11.3	14	12.9	8.4	11.2	8.8	8.2	13.7	7.6	8.1	9.2	5	10.3	8.3	9.2	7.8	13.2
		±0.8^{e}	±1.9^{g}	±0.9^{f}	±0.8^{bcd}	±0.9^{e}	±0.7^{cd}	±1.1^{bcd}	±0.9^{fg}	±0.7^{b}	±0.9^{bc}	±0.9^{d}	±2.5^{a}	±0.8^{e}	±0.7^{bcd}	±1.1^{d}	±0.8^{bc}	±0.8^{fg}
	Mean	10.8	12	12.4	8	10.1	8.4	7.6	13.1	7.4	7.6	8.7	4.5	8.8	7.8	8.7	7.4	13
		±0.7^{de}	±1.1^{ef}	±0.8^{f}	±0.6^{b}	±0.4^{cd}	±0.6^{b}	±0.8^{b}	±0.8^{f}	±0.4^{b}	±0.7^{b}	±0.7^{bc}	±0.7^{a}	±0.7^{bc}	±0.7^{b}	±0.7^{bc}	±0.6^{b}	±0.4^{f}
Fruit TSS	2009	18.2	19.1	19.8	18.8	18.4	19.2	15.8	18.4	18.5	18.3	18.5	18.5	19.6	19.1	19.6	15.8	20.1
		±0.4^{b}	±0.8^{bcd}	±0.6^{de}	±1.1^{bc}	±0.4^{b}	±1.6^{bc}	±0.9^{a}	±1.9^{b}	±1.2^{bc}	±0.2^{bcd}	±0.3^{b}	±1.3^{bc}	±0.4^{cde}	±0.4^{bcd}	±0.6^{cde}	±0.9^{a}	±1.4^{e}
	2010	19.1	18.3	19.9	19.6	17.6	20	16.4	17.5	19.4	19	19	19.6	19.1	19.2	20.4	16.4	21.1
		±0.8^{de}	±1.2^{cd}	±1.4^{ef}	±1.3^{ef}	±0.5^{c}	±1.4^{ef}	±1.0^{a}	±2.3^{bc}	±1.7^{def}	±0.8^{de}	±0.7^{de}	±1.0^{ef}	±0.7^{de}	±1.0^{def}	±0.6^{fg}	±1.1^{ab}	±1.3^{g}
	Mean	18.7	18.7	19.9	19.2	18	19.6	16.1	18	19	18.7	18.8	19.1	19.4	19.2	20	16.1	20.6
		±0.6^{bc}	±0.6^{bc}	±0.1^{cde}	±0.6^{bcd}	±0.6^{b}	±0.6^{cde}	±0.4^{a}	±0.6^{b}	±0.6^{bcd}	±0.5^{bc}	±0.4	±0.8	±0.4^{cd}	±0.1	±0.6^{de}	±0.4^{a}	±0.7^{e}
TA % mallic acid	2009	0.7	0.5	1.2	0.7	1	2.6	1.2	1	0.9	0.8	0.8	0.7	1.2	0.8	2.1	0.8	1.1
		±0.0^{b}	±0.0^{a}	±0.0^{j}	±0.0^{b}	±0.0^{g}	±0.0^{l}	±0.0^{i}	±0.0^{g}	±0.0^{f}	±0.0^{e}	±0.0^{e}	±0.0^{c}	±0.0^{i}	±0.0^{d}	±0.0^{k}	±0.0^{d}	±0.0^{h}
	2010	0.6	0.4	1.1	0.6	0.9	2.5	1.1	0.9	0.9	0.7	0.7	0.7±	1.1	0.7	2.1	0.7	1
		±0.03^{b}	±0.07^{a}	±0.01^{j}	±0.01^{b}	±0.04^{g}	±0.03^{l}	±0.03^{i}	±0.01^{g}	±0.02^{f}	±0.02^{e}	±0.01^{d}	0.02^{c}	±0.03^{i}	±0.03^{de}	±0.03^{k}	±0.01^{d}	±0.01^{h}
	Mean	0.65	0.5	1.2	0.7	1	2.6	1.2	1	0.9	0.8	0.8	0.7	1.2	0.8	2.1	0.8	1.1
		±0.1^{b}	±0.1^{a}	±0.1^{e}	±0.1^{b}	±0.1^{cd}	±0.1^{g}	±0.1^{e}	±0.1^{cd}	±0.0^{c}	±0.1^{b}	±0.1^{b}	±0.0^{b}	±0.1^{e}	±0.1^{b}	±0.0^{f}	±0.1^{b}	±0.1^{de}

Table 2 *(Concluded)*

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
TSS/TA		2009	28.3 ±0.7^{j}	40.5 ±2.0^{l}	16.2 ±0.4^{d}	29 ±1.8^{k}	18.9 ±0.5^{e}	7.3 ±0.6^{a}	13.7 ±0.9^{c}	18.8 ±2.0^{e}	19.9 ±1.4^{ef}	22.4 ±0.5^{g}	23.7 ±0.6^{h}	25.1 ±1.8^{i}	16.9 ±0.4^{d}	24 ±0.9^{hi}	9.1 ±0.4^{b}	20.3 ±1.2^{f}	19.3 ±1.4^{ef}
		2010	33.7 ±1.5^{j}	50.8 ±2.2^{k}	18 ±0.6^{d}	34.5 ±2.3^{j}	21.5 ±1.2^{e}	7.9 ±0.6^{a}	15.2 ±1.1^{c}	21.5 ±2.0^{e}	22.7 ±2.1^{ef}	25.8 ±1.2^{g}	27.1 ±1.2^{gh}	29.8 ±1.8^{i}	18.6 ±0.7^{d}	27.9 ±2.1^{h}	9.9 ±0.3	23.5 ±1.5^{f}	21.9 ±1.4^{e}
		Mean	31 ±3.8^{h}	45.7 ±7.3^{i}	17.1 ±1.3^{cd}	31.8 ±3.9^{h}	20.2 ±1.8^{cdef}	7.6 ±0.4^{a}	14.5 ±1.1^{bc}	20.2 ±1.9^{cdef}	21.3 ±2.0^{defg}	24.1 ±2.4^{efg}	25.4 ±2.4^{fgh}	27.5 ±3.3^{gh}	17.8 ±1.2^{cde}	26 ±2.8^{fgh}	9.5 ±0.6^{ab}	21.9 ±2.3^{defg}	20.6 ±1.8^{cdef}
Pulp (%)		2009	90.6 ±0.5^{f}	93.4 ±0.4^{i}	92.1 ±0.4^{h}	88.8 ±0.5^{b}	90 ±0.4^{de}	89.1 ±0.6^{b}	86.5 ±0.6^{a}	92 ±0.5^{h}	86.4 ±0.9^{a}	89.2 ±0.5^{bc}	90.2 ±0.4^{ef}	89.6 ±0.6^{cd}	91.3 ±0.3^{g}	88.9 ±0.6^{b}	90.3 ±0.4^{ef}	86.5 ±0.6^{a}	92.2 ±0.8^{h}
		2010	90 ±0.5^{e}	91.4 ±3.6^{f}	91.5 ±0.6^{f}	88.5± 2.2^{bcd}	88.6 ±0.5^{bcd}	88.1 ±0.7^{bc}	85.4 ±0.8^{a}	91.1 ±0.5^{f}	85.2 ±1.3^{a}	88.1 ±0.8^{bc}	89.4 ±0.6^{de}	88.7 ±1.2^{cd}	89.9 ±0.6^{e}	87.4 ±0.7^{b}	89.2 ±0.6^{cde}	85.5 ±0.8^{a}	91.8 ±0.8^{f}
		Mean	90.3 ±0.4^{cdef}	92.4 ±1.4^{g}	91.8 ±0.4^{fg}	88.7 ±0.2^{bc}	89.3 ±1.0^{bcd}	88.6 ±0.7^{bc}	86 ±0.8^{a}	91.6 ±0.6^{efg}	85.8 ±0.8^{a}	88.7 ±0.8^{bc}	89.8 ±0.6^{bcde}	89.2 ±0.6^{bcd}	90.6 ±1.0^{defg}	88.2 ±1.1^{b}	89.8 ±0.8^{bcde}	86 ±0.7^{a}	92 ±0.3^{fg}
Colour	L*	2009	22.8 ±2.2^{ab}	22 ±1.7^{ab}	16.7 ±0.8^{ab}	12.7 ±0.2^{a}	12.8 ±0.9^{a}	13.5 ±0.3^{a}	14.5 ±0.3^{ab}	14.9 ±1.3^{ab}	28.7 ±1.3^{c}	15.5 ±1.3^{ab}	18.5 ±4.1^{ab}	20.6 ±0.0^{ab}	15.7 ±0.0^{ab}	15.5 ±2.0^{ab}	18.4 ±2.4^{ab}	16 ±1.1^{ab}	18.7 ±3.6^{ab}
		2010	23 ±0.2^{j}	22 ±0.1^{i}	17.7 ±0.1^{g}	12.8 ±0.1^{a}	14 ±0.2^{b}	14.8 ±0.2^{c}	15.8 ±0.2^{d}	16.3 ±0.2^{e}	28 ±0.2^{k}	14.7 ±0.2^{c}	17.5 ±0.3^{g}	22.9 ±0.3^{j}	16.7 ±0.3^{f}	17.8 ±0.2^{g}	19.6 ±0.3^{h}	14.3 ±0.4^{b}	20 ±0.4^{h}
		Mean	22.9 ±0.1^{h}	22 ±0.0^{h}	17.2 ±0.7^{def}	12.8 ±0.1^{a}	13.4 ±0.8^{ab}	14.2 ±0.9^{abc}	15.2 ±0.9^{bcd}	15.6 ±1.0^{cd}	28.4 ±0.5^{i}	15.1 ±0.6^{bcd}	18 ±0.7^{efg}	21.8 ±1.6^{h}	16.2 ±0.7^{cde}	16.7 ±1.6^{de}	19 ±0.8^{fg}	15.2 ±1.2^{bcd}	19.4 ±0.9^{g}
	A	2009	2.8 ±0.8^{a}	3.3 ±0.4^{ab}	3.7 ±0.6^{ab}	7.1 ±0.7^{cd}	4 ±0.6^{b}	5.4 ±0.1^{b}	3.8 ±0.0^{ab}	2.6 ±0.3^{a}	4 ±0.9^{ab}	7.2 ±0.8^{cd}	8 ±0.0^{d}	2.8 ±0.1^{a}	4.3 ±0.3^{ab}	7.4 ±1.0^{cd}	2.7 ±1.3^{a}	7.5 ±0.1^{cd}	4 ±1.0^{ab}
		2010	2.8± 0.3^{a}	3.4 ±0.3^{ab}	4.4 ±0.4^{de}	7.5 ±0.4^{g}	5 ±0.3^{e}	5.8 ±0.4^{f}	4.2 ±0.4^{cd}	3.6 ±0.3^{bc}	4.4 ±0.4^{de}	7.7 ±0.4^{gh}	8.4 ±0.4^{h}	4.2 ±0.6^{cd}	4.3 ±0.3^{de}	7.8 ±0.4^{gh}	3.2 ±0.3^{ab}	7.9 ±0.3^{gh}	4.6 ±0.3^{de}
		Mean	2.8 ±0.0^{a}	3.4 ±0.1^{abc}	4.1 ±0.5^{bcd}	7.3 ±0.3^{f}	4.5 ±0.7^{d}	5.6 ±0.3^{e}	4 ±0.3^{bcd}	3.1 ±0.7^{ab}	4.2 ±0.3^{cd}	7.5 ±0.4^{f}	8.2 ±0.3^{f}	3.5 ±1.0^{abcd}	4.3 ±0.0^{cd}	7.6 ±0.3^{f}	3 ±0.4^{a}	7.7 ±0.3^{f}	4.3 ±0.4^{cd}
	b	2009	12.4 ±7.4^{abc}	8.6 ±0.4^{ab}	9.7 ±0.7^{abc}	8.9 ±0.3^{ab}	7.2 ±0.7^{a}	8.4 ±0.5^{ab}	7.4 ±0.0^{ab}	7.6 ±0.9^{ab}	12.6 ±4.0^{bc}	10.9 ±1.3^{abc}	11 ±0.3^{abc}	15 ±0.1^{c}	9.7 ±0.9^{abc}	11.4 ±1.8^{abc}	11 ±1.4^{abc}	12.4 ±1.0^{abc}	12.2 ±1.1^{abc}
		2010	13.1 ±0.2^{def}	9.3 ±0.2^{b}	10.4 ±0.2^{bc}	9.8 ±03^{bc}	8.2 ±0.3^{a}	9.4 ±0.3^{bc}	10 ±2.6^{bc}	7.6 ±0.3^{a}	13.7 ±0.2^{f}	11.9 ±0.3^{d}	12 ±0.3^{de}	16 ±0.3^{g}	10.7 ±0.3^{c}	12.4 ±0.2^{def}	12 ±0.3^{de}	13.4 ±0.4^{f}	13.2 ±0.3^{ef}
		Mean	12.8 ±0.5^{e}	9 ±0.5^{ab}	10.1 ±0.5^{bc}	9.4 ±0.6^{ab}	7.7 ±0.7^{a}	8.9 ±0.7^{ab}	8.7 ±1.8^{ab}	7.6 ±0.0^{a}	13.2 ±0.8^{e}	11.4 ±0.7^{cde}	11.5 ±0.7^{cde}	15.5 ±0.7^{f}	10.2 ±0.7^{bcd}	11.9± 0.7^{de}	11.5 ±0.7^{cde}	12.9 ±0.7^{e}	12.7 ±0.7^{e}
Stone wt (g)		2009	2.3 ±0.1^{d}	2.2 ±0.3^{d}	2.5 ±0.3^{e}	1.7 ±0.1^{abc}	2.4 ±0.2^{de}	1.8 ±0.1^{bc}	1.8 ±0.2^{abc}	2.8 ±0.3^{f}	1.6 ±0.1^{ab}	1.6 ±0.3^{a}	1.8 ±0.1^{bc}	1.9 ±0.2^{c}	2.3 ±0.1^{d}	1.6 ±0.3^{ab}	1.8 ±0.1^{bc}	1.8 ±0.2^{abc}	3.3 ±0.5^{g}
		2010	2.5 ±0.1^{c}	2.5 ±0.3^{c}	2.8 ±0.3^{d}	2 ±0.1^{ab}	2.7 ±0.2^{cd}	2.1 ±0.1^{ab}	2 ±0.2^{ab}	3.1 ±0.3^{e}	1.9 ±0.1^{a}	1.8 ±0.3^{a}	2.1 ±0.1^{ab}	2.2 ±0.2	2.5 ±0.1^{c}	1.9 ±0.3^{a}	2.1 ±0.1^{ab}	2 ±0.2^{ab}	3.6 ±0.5^{f}
		Mean	2.4±0.1^{bc}	2.1 ±0.1^{ab}	2.7 ±0.2^{cd}	1.9 ±0.2^{a}	2.1 ±0.5^{ab}	2 ±0.2^{ab}	1.9 ±0.1^{ab}	3 ±0.2^{d}	1.8 ±0.2^{a}	1.7 ±0.1^{a}	2 ±0.2^{ab}	2.1 ±0.2^{ab}	2.2 ±0.1^{abc}	1.8 ±0.2^{a}	2 ±0.2^{ab}	1.9 ±0.1^{ab}	3.5 ±0.2^{e}

Values represented as mean ± SD (n=20); For each row, values followed by the same letters are not significantly different at $P < 0.05$ as measured by the Duncan multiple range test by the statistical software, SPSS 11.5 ver. for windows.

1. Safeda, 2. Selection-73, 3. Turtuk CP-3, 4. Hanu Selection-3, 5. Garkhond Selection-1, 6. Hanu Selection-5, 7. Selection-21, 8. Tokpopa, 9. Saspol Selection-3, 10. Turtuk CP-2, 11. Selection-13. 12. Achinathang-5, 13. Afghani, 14. Charmagz, 15. Raktsey Karpo, 16. Halman, 17. Raktsey Karpo Chenmo

Table 3 Correlation matrix among variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Fruit wt (g) (1)	1.000																			
Fruit length (mm) (2)	.928(**)	1.000																		
Fruit dia (mm) (3)	.975(**)	.913(**)	1.000																	
Fruit width (mm) (4)	.853(**)	.793(**)	.841(**)	1.000																
Pulp (%) (5)	.863(**)	.933(**)	.890(**)	.747(**)	1.000															
Pulp TA (6)	-0.054	0.033	-0.072	-0.008	-0.039	1.000														
Pulp TSS/TA (7)	0.145	0.091	0.184	0.106	0.264	-.818(**)	1.000													
Pulp colour (L*) (8)	0.079	0.082	0.032	-0.018	0.019	-0.251	0.307	1.000												
Pulp colour (b) (9)	-0.228	-0.19	-0.256	-0.469	-0.222	-0.256	0.135	.593(*)	1											
Stone wt (g) (10)	.897(**)	.852(**)	.862(**)	.774(**)	.686(**)	0.017	-0.072	0.056	-0.071	1										
Bud break season (11)	-0.017	-0.072	0.037	0.128	0.141	0.097	0.088	0.012	-0.065	-0.109	1									
Blossom season (12)	0.019	0.033	0.064	0.25	0.119	.485(*)	-0.271	-0.096	-0.294	0.034	.809(**)	1								
End of blossoming (13)	0.216	0.322	0.278	0.335	0.459	0.306	-0.142	-0.301	-0.415	0.165	.607(**)	.765(**)	1							
Harvest season (14)	0.045	0.032	0.091	0.293	0.11	0.303	-0.365	-.700(**)	-.653(**)	0.052	0.414	.593(*)	.713(**)	1						
Fruit develop period (15)	0.021	-0.061	0.021	0.15	-0.065	0.142	-0.314	-0.469	-.580(*)	-0.014	0.111	0.148	0.146	.610(**)	1					
Leaf fall season (16)	0.059	-0.076	0.076	0.179	-0.092	0.233	-0.249	-0.126	-0.29	0.052	0.454	.571(*)	0.297	.543(*)	0.27	1				
Blushing of fruit skin (17)	-0.053	0.016	-0.042	-0.299	0.07	-0.369	0.346	0.348	.595(*)	-0.054	-0.337	-.505(*)	-0.229	-.501(*)	-0.365	-.606(**)	1			
Acidity of juice (18)	-0.263	-0.302	-0.309	-0.19	-0.372	.591(*)	-.483(*)	-0.29	-0.359	-0.184	-0.027	0.268	0.091	0.145	0.24	-0.104	-0.32	1		
Stone adherence (19)	0.445	0.406	0.466	.579(*)	0.442	0.202	-0.34	-0.317	-0.416	0.388	0.316	0.344	.496(*)	.714(**)	.535(*)	0.439	-0.358	-0.251	1	
Stone surface (20)	-0.315	-0.415	-0.339	-0.198	-.531(*)	0.389	-0.423	-0.004	-0.329	-0.28	-0.041	0.256	0.008	0.116	0.126	0.291	-0.4	.658(**)	-0.15	1

**Correlations significant at $P < 0.01$, *Correlations significant at $P < 0.05$

Table 4 Eigenvalues and proportion of total variability among apricot genotypes as examined by first 10 principal components

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Eigenvalues	7.123	6.5	3.652	2.568	2.065	1.962	1.41	1.197	0.87	0.739
Variance (%)	23.744	21.667	12.175	8.561	6.884	6.54	4.699	3.991	2.899	2.463
Cummulative (%)	23.744	45.412	57.586	66.147	73.031	79.572	84.271	88.262	91.161	93.624

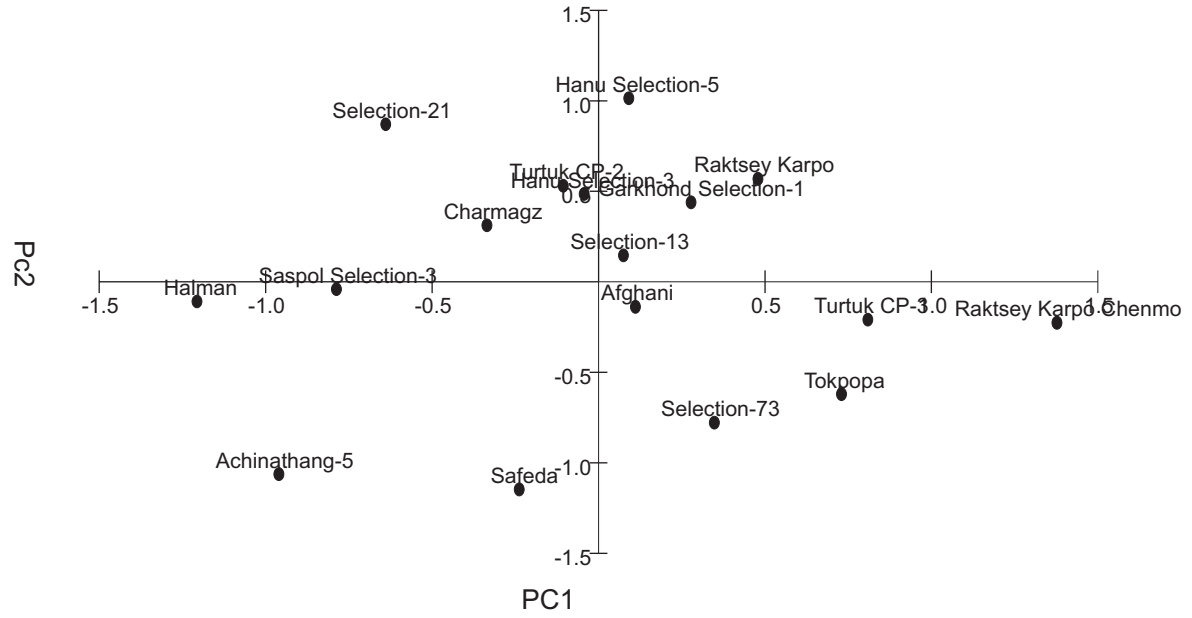

Fig 1 Projection of individual genotypes in the space of the first and second principal components

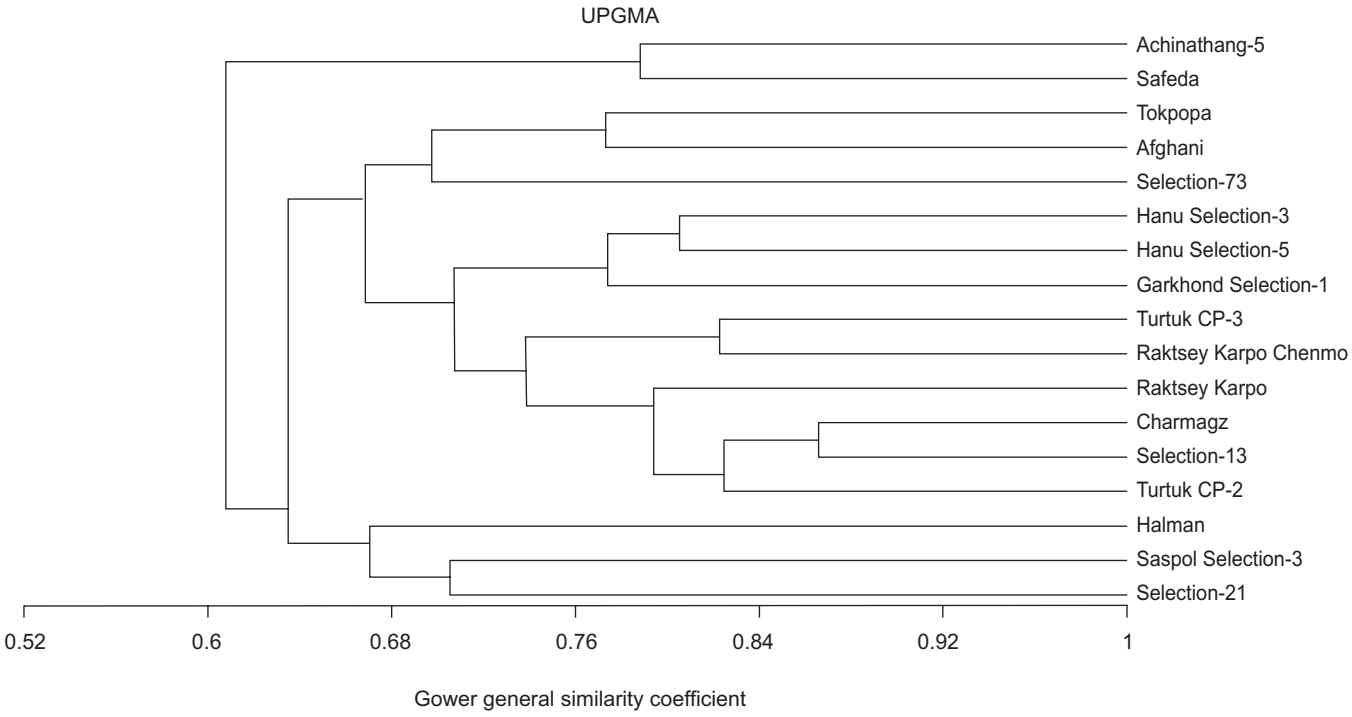

Fig 2 UPGMA phenogram showing relationship within the 17 apricot genotypes

components (PC1-PC3) (Table 4). PC1 represents mainly fruit weight, fruit length, fruit diameter, fruit width, TSS, end of blossoming and account for 23.7% of the variance (Table 5). PC2 represent blossom season, harvest season, flesh colour, acidity of juice. The fruit length, TSS/TA, pulp lightness colour (L*), blushing of fruit skin and stone size were determined in negative PC2. Fruit thickness, TSS, pulp lightness (L*) and yellowness colour (b), bud break season and blossom season were determined in positive PC3 while fruit development period was determined in negative PC3.

The apricot genotypes were distributed in continuous gradients rather than in discrete groups within the space of

Table 5 Eigenvectors in the first 10 principal components from PCA

Variable	Eigenvectors									
	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Fruit wt (g)	0.301	–0.191	–0.079	–0.068	–0.046	–0.057	0.088	0.033	0.178	–0.135
Fruit length (mm)	0.302	–0.205	–0.053	–0.053	–0.107	0.019	0.005	–0.053	–0.12	–0.075
Fruit dia (mm)	0.307	–0.185	–0.076	–0.016	–0.062	–0.073	0.052	0.045	0.204	–0.104
Fruit thickness (mm)	0.114	0.037	0.268	0.058	–0.395	0.092	0.203	0.307	0.331	0.038
Fruit width (mm)	0.311	–0.108	–0.146	–0.033	0.054	–0.083	0.005	0.196	0.057	0.232
Pulp TSS	0.224	–0.03	0.321	0.033	–0.14	0.057	0.034	–0.191	–0.355	–0.009
Pulp (%)	0.307	–0.184	0	0.093	–0.088	–0.006	–0.131	–0.051	–0.07	–0.157
TA of pulp	0.097	0.225	0.027	–0.3	–0.312	0.095	0.041	–0.05	–0.283	–0.146
TSS/TA	–0.043	–0.229	0.07	0.349	0.09	–0.27	–0.247	0.115	0.202	0.038
Pulp colour (L*)	–0.063	–0.223	0.265	–0.213	0.177	–0.12	0.062	0.171	–0.225	0.016
Pulp colour (a)	–0.107	0.18	0.022	0.441	0.024	0.1	0.129	0.04	–0.07	0.159
Pulp colour (b)	–0.162	–0.16	0.32	0.002	0.002	0.281	0.265	0.034	0.006	–0.046
Stone wt (g)	0.274	–0.168	–0.074	–0.143	–0.061	0.123	0.189	0.099	0.165	0.083
Bud break season	0.144	0.169	0.29	0.182	0.212	–0.079	–0.098	0.316	0.018	–0.131
Blossom season	0.197	0.24	0.223	–0.015	0.024	–0.078	–0.117	0.258	–0.115	0.171
End of blossoming	0.257	0.158	0.14	0.072	0.027	0.035	–0.346	–0.099	–0.102	0.184
Harvest season	0.197	0.276	–0.125	0.15	0.113	0.073	–0.072	–0.13	0.053	0.207
Fruit development period	0.076	0.183	–0.312	0.042	0.25	0.057	–0.045	0.041	–0.069	–0.425
Leaf fall season	0.138	0.207	0.078	0.014	0.169	–0.26	0.374	–0.098	0.156	0.122
Fruit Shape	–0.172	–0.018	–0.205	0.049	–0.115	0.254	0.002	0.398	0.09	0.228
Ground colour of fruit skin	0.085	0.146	0.365	–0.136	0.028	0.189	–0.073	–0.252	0.206	0.224
Blushing of fruit skin	–0.119	–0.224	0.132	0.019	–0.03	0.291	–0.277	–0.302	0.212	–0.098
Flesh colour	0.052	0.272	0.077	–0.123	0.086	0.14	–0.199	–0.101	0.511	–0.262
Acidity of juice	–0.058	0.218	–0.094	–0.3	–0.248	–0.018	–0.276	0.27	0.026	–0.125
Degree of flesh hollowness	–0.057	0.138	–0.196	0.137	–0.392	–0.18	0.253	–0.339	0.126	0.128
Stone size	0.052	–0.205	–0.21	–0.135	0.027	0.172	–0.296	–0.062	–0.027	0.498
Stone shape	–0.042	–0.039	–0.014	–0.333	0.443	0.239	0.249	0.025	0.091	0.089
Stone adherence	0.268	0.096	–0.132	0.057	0.254	0.14	0.186	–0.127	–0.063	0.009
Stone surface	–0.085	0.2	–0.033	–0.378	0.002	–0.331	–0.032	0.001	0.051	0.202
Kernel taste	–0.099	–0.178	0.152	–0.149	0.079	–0.478	–0.066	–0.169	0.138	0.008

the first two principal components (Fig 1). The phenogram obtained from UPGMA clustering of the similarity matrix is presented in Fig 2. A line across the phenogram at 0.6 similarity level emphatically distinguished the genotypes into three main clusters. The first cluster represents Achinathang-5 and Safeda genotypes while the third cluster represents Halman, Saspol Selection 3 and Selection 21. On the other hand, the second cluster includes the remaining genotypes. The genotypes that are closely distributed within the space of the first two principal components are clustered together in the phenogram.

CONCLUSIONS

In view of the fact that apricot grown in the region could be genetically diverse than those grown worldwide due to geographical barrier, a need for the inventory of apricot genetic resources and morphological characterization was felt. The field gene bank and data base of apricot grown in trans-Himalayan Ladakh region will make a fundamental contribution to further genetic improvement of apricot for characters such as late blossoming, fruit TSS, stone characteristics etc. In view of the unique characteristics, the genotypes can be explored for crop improvement worldwide.

ACKNOWLEDGEMENTS

Authors are grateful to Defence Research and Development Organisation, New Delhi for providing the financial support. Thanks are due to Mr Konchok Targais and Mr Tashi Dorjey for technical assistance.

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