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Morphological and pomological diversity among apricot (*Prunus armeniaca*) genotypes grown in India

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ABSTRACT

Forty nine apricot (*Prunus armeniaca* L.) genotypes collected from NBPGR, New Delhi, and North West Himalayan region of India and studied to assess the overall degree of polymorphism, detect similarities among important pomological, fruit quality and yield parameters. Genotypes differed significantly for above traits. Thirteen variables were scored and subjected to multivariate analysis. Results showed a considerable phenotypic diversity among apricot genotypes. The cluster analysis classified genotypes into two major groups according to their potential characteristics. The first group was found superior in terms of fruit and yield related characteristics and second group in fruit quality attributes. Principal component analysis (PCA) revealed that the first PC, which is the most important component, explained 46.68 % of total variation and was positively related to number of fruits/plant, fruit length, fruit diameter, fruit weight, stone length, stone diameter, stone weight, kernel weight, kernel diameter, kernel length and yield/plant and negatively related to acidity and genotypes in CITH-AP 1, CITH-AP 2, CITH-AP 3, Erani, CITH-AP 36, Afglani and Harcot were found unique for fruit and yield attributing traits.

Key words: Apricot, Morphological, Pomological diversity

Apricot is one of the most cultivated stone fruits in the world (Vilanova *et al*. 2003; Ercisli 2009). It belongs to the family Rosaceae, the genus *Prunus* L., the subgenus *Prunophora* Focke, and the species *Armeniaca* (Lam.) Koch (Rehder 1967). There are four species and one naturally occurring inter specific hybrid under the generic term of apricot. These are: *P. armeniaca* L., the cultivated apricot; *P. sibirica* L., the Siberian apricot; *P. mandshurica* (Maxim.) Koehne, the Manchurian apricot; *P. mume* (Siebold) Siebold & Zucc., the Japanese apricot; and *Prunus* × *dasycarpa* Ehrh., the black or purple apricot. Among them, *P. armeniaca* is the most widely cultivated (Uzun *et al.* 2007, Yilmaz *et al*. 2009, Uzun *et al.* 2010). In India, different apricot genotypes are grown in J&K, Himachal Pradesh, Uttarakhand and Punjab which consist of an area 0.050 lakh ha, production 0.180 lakh tonnes and productivity is 3.60 tonnes/ha (FAO,2012) possess high genetic variability.

Genetic variability is the prerequisite for any plant breeding program (Khush 2002). The development of new fruit cultivars generally has been based on genetic resources. Germplasm collection and characterization are essential stages of breeding programs. Mainly germplasm collection and characterization are performed by describing phenological, pomological, and morphological characteristics such as tree vigor and growth habit, fruit quality features, leaf, stone, flower, stigma and stylus, pollen, blooming, and harvest time. Finding and utilization of diverse apricot genotypes are prime concern for apricot for use in breeding and to identify their desirable fruit and yield characteristics. These traits are in common use for elucidation of wide genetic diversity in different field and horticultural crops (Blazek 2007). Leaf flower and related fruit traits, have been used as main morphological traits in inter-specific hybrids characterization of many *Prunus* species (Jakubowski 2002, Ertekin *et al.* 2006). These morphological traits are the primary markers utilized in germplasm management (Karimi *et al.* 2008). Although newly developed molecular markers are valuable techniques in gene based diversity studies, however these procedures have disadvantage of high cost (Ahmad *et al*. 2004 Bouhadida *et al.* 2005). In contrast, morphological traits could feasibly be used for parental selection and along with molecular techniques are of highly appreciated procedures for description and germplasm classification of plants. Statistical methods such as: principal component analysis and cluster analysis have been employed as powerful options for plant cultivar and accession screenings. Morphological criteria have been widely used as important markers in plant breeding programs (Ogasanovic *et al.* 2007, Karimi *et al.* 2008). The objective of the present study was to investigate the morphological and pomological traits diversity among 49 apricot

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genotypes as an initial step aiming to the national and international germplasm characterization and preservation of these precious fruit trees for future breeding programs. Besides this, the study will also be useful to harness the economic advantage associated with this valuable crop through survey and collection from potential areas.

MATERIALS AND METHODS

The experiment was conducted on 7 years old trees which were budded on seedlings planted at a spacing of 5.0 m × 5.0 m at ICAR–Central Institute of Temperate Horticulture, Srinagar, J&K, India. The Research farm at Srinagar is situated at a latitude of 34° 05'N and longitude of 74° 50'E and at an altitude of 1640 m above mean sea level. Recommended package of practices followed for healthy crop. The average maximum temperature 19.63°C, minimum 6.52 °C, rainfall 750 mm and relative humidity 58.35%, evaporation 2.45/day and soil characteristics, viz. pH= 6.81, EC = 0.36 dS/m were recorded in during all growing seasons. The primary selection criterion was based on fruit and yield attributes of the genotypes (Table 1). Individual genotypes were marked in the field. The data were recorded at the time of fruit maturity during summer (June–July) seasons from. 2008–2012 and data pooled for analysis. Total numbers of fruits were counted per plant. Twenty fruits from each genotype were randomly selected and data were collected on fruit length (mm), fruit weight (g), fruit diameter (mm), pulp thickness (mm), stone length (mm), stone diameter (mm), stone weight (g), TSS (º Brix), acidity (%) and fruit yield (kg/plant) in apricot genotypes. Fruit weight was measured using Sartorius balance with accuracy of 0.001 g. The length and diameter of the fruit was measured with a digital vernier caliper. The measurement of fruit length was made on the polar axis, *i.e*. between the apex and stylar end. The maximum width of the fruit was measured in the direction perpendicular to the polar axis. The stone were manually separated from the fruits, and traits were measured as above. Total soluble solids (TSS) and titrable acidity were determined by method given in AOAC (1994). The experiment was conducted under randomized block design with three replication and pooled data of all the years were analyzed as per the method suggested by Gomez and Gomez (1984). To find out significance level, ANOVA performed using PROC GLM and clustering of genotypes into similarity groups was performed using the method tree procedure PROC CLUSTER based on average distance. In order to identify the patterns of morphological variation and contribution of traits, principal component analysis (PCA) was conducted as PROC PRINCOP in the SAS 9.3 software (SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

All the genotypes varied (60–1957.33) significantly in relation to number of fruits/plant which actually contributes to the economical yield. Maximum number of fruits per plant was recorded in Afghani (1957.33) followed by CITH–AP–1 (1868.33) and CITH–AP–3 (1656.67) and it was least in Viva Gold (60). Yield is the economic potential of plants considered most important while making selection and further improvement. Yield varied widely among the forty nine genotypes which ranged from 2.26 to 110.40 kg/plant. The most productive selection CITH–Apricot–1 yielded 110.40 kg/plant followed by CITH–Apricot–2 (73.14 kg/plant) and CITH–Apricot–3 (53.54 kg/plant). Low yielding genotype Viva Gold produced only 2.26 kg/plant (Table 2

Table 1 List and source of genotypes used in study

Genotype	Source	Genotype	Source	Genotype	Source	Genotype	Source	Genotype	Source
Afghani	NBPGR, New Delhi	CITH–AP 8	CITH, Srinagar	CITH–AP 18	CITH, Srinagar	CITH–AP 29	CITH, Srinagar	Harcot	NBPGR, New Delhi
Balcota	NBPGR, New Delhi	CITH–AP 9	CITH, Srinagar	CITH–AP 19	CITH, Srinagar	CITH–AP 30	CITH, Srinagar	Heartly	NBPGR, New Delhi
Chinese apricot	NBPGR, New Delhi	CITH–AP 10	CITH, Srinagar	CITH–AP 20	CITH, Srinagar	CITH–AP 31	CITH, Srinagar	Nari	NBPGR, New Delhi
CITH–AP–1	CITH, Srinagar	CITH–AP 11	CITH, Srinagar	CITH–AP 21	CITH, Srinagar	CITH–AP 32	CITH, Srinagar	New Castle	NBPGR, New Delhi
CITH–AP–2	CITH, Srinagar	CITH–AP 12	CITH, Srinagar	CITH–AP 22	CITH, Srinagar	CITH–AP 36	CITH, Srinagar	Rival Apricot	NBPGR, New Delhi
CITH–AP–3	CITH, Srinagar	CITH–AP 13	CITH, Srinagar	CITH–AP 23	CITH, Srinagar	CITH–AP 37	CITH, Srinagar	Tilton Apricot	NBPGR, New Delhi
CITH–AP–4	CITH, Srinagar	CITH–AP 14	CITH, Srinagar	CITH–AP 24	CITH, Srinagar	Communis	NBPGR, New Delhi	Tokpopa Nimu	NBPGR, New Delhi
CITH–AP–5	CITH, Srinagar	CITH–AP 15	CITH, Srinagar	CITH–AP 25	CITH, Srinagar	Communis Holy	NBPGR, New Delhi	Turkey	NBPGR, New Delhi
CITH–AP–6	CITH, Srinagar	CITH–AP 16	CITH, Srinagar	CITH–AP 27	CITH, Srinagar	Erani	NBPGR, New Delhi	Viva Gold	NBPGR, New Delhi
CITH–AP–7	CITH, Srinagar	CITH–AP 17	CITH, Srinagar	CITH–AP 28	CITH, Srinagar	Fairmed–cester	NBPGR, New Delhi		

Table 2 Fruit and yield characteristic of apricot genotypes grown commercially in North West Himalayan region of India

Variety	No. of fruits	Fruit wt. (g)	Fruit length (mm)	Fruit dia. (mm)	TSS (°Brix)	Stone wt. (g)	Stone length (mm)	Stone dia. (mm)	Kernel wt. (g)	Kernel length (mm)	Kernel dia. (mm)	Acidity (%)	Yield (kg/ plant)
Afghani	1957.33	36.86	38.26	36.30	20.98	2.37	22.11	18.48	0.78	14.85	12.27	0.56	49.60
Balcota	836.67	37.62	41.20	39.98	15.70	3.24	25.15	19.79	1.11	19.20	12.60	1.01	22.79
Chinese Apricot	622.00	45.42	43.38	44.48	14.06	3.48	27.12	22.25	1.27	18.45	12.58	0.78	29.08
CITH□AP 1	1868.33	81.94	49.00	53.89	17.55	3.71	26.55	23.69	1.04	17.49	13.98	0.53	110.40
CITH□AP 2	1575.67	70.10	47.40	53.71	16.70	4.34	28.22	24.36	1.40	17.47	14.59	0.72	73.14
CITH□AP 3	1656.67	50.51	43.63	48.70	17.11	3.50	25.25	22.90	1.53	16.45	13.72	0.86	53.54
CITH□AP 4	220.00	63.67	45.81	49.40	16.16	2.52	23.17	21.55	1.35	15.23	12.82	0.96	5.58
CITH□AP 5	1184.00	28.30	35.78	36.51	15.72	2.51	22.02	19.66	1.02	14.06	12.02	0.76	22.00
CITH□AP 6	653.00	29.22	35.58	37.40	16.27	2.56	21.34	18.68	1.07	12.96	10.79	0.42	14.32
CITH□AP 7	954.33	31.35	41.22	37.37	19.16	2.66	25.98	18.60	1.24	18.55	12.88	0.80	26.73
CITH□AP 8	422.00	65.93	47.83	48.20	16.62	3.70	27.51	21.94	1.39	19.79	13.60	1.15	21.07
CITH□AP 9	770.33	37.66	41.58	40.02	21.59	3.76	27.75	21.06	1.30	19.57	14.48	0.66	23.36
CITH□AP□10	267.00	41.85	38.53	41.62	20.69	2.66	23.70	19.72	0.85	16.57	12.52	0.58	6.49
CITH□AP 11	239.33	64.38	46.58	47.40	18.52	3.49	28.54	23.28	1.28	18.49	14.16	0.55	14.39
CITH□AP 12	465.00	31.13	36.70	38.40	22.49	2.72	22.18	19.60	1.00	16.75	13.76	0.71	11.64
CITH□AP 13	432.33	35.05	39.39	39.77	16.53	3.01	25.30	19.31	1.14	18.94	14.47	0.74	7.04
CITH□AP 14	559.00	32.63	35.21	39.99	20.44	3.22	21.75	21.71	1.31	15.98	15.07	0.89	15.05
CITH□AP 15	320.67	19.70	34.27	33.19	22.00	2.40	23.43	17.86	1.05	17.09	11.90	0.30	5.40
CITH□AP 16	415.00	24.30	35.77	34.38	19.01	2.53	23.40	18.45	0.83	17.37	13.62	1.05	8.76
CITH□AP 17	555.00	24.27	34.74	35.29	20.16	2.40	23.97	18.91	1.16	16.29	13.57	0.62	13.73
CITH□AP 18	560.00	32.73	36.23	32.54	15.90	2.38	23.49	18.48	1.01	16.95	13.30	0.65	9.62
CITH□AP 19	384.00	28.35	37.99	38.98	22.29	2.89	24.38	19.64	1.21	17.21	13.25	0.24	7.80
CITH□AP 20	676.67	28.02	37.29	38.79	17.80	2.57	22.74	18.82	0.93	15.63	12.07	0.40	11.23
CITH□AP 21	622.00	27.28	37.13	36.76	22.15	2.79	23.60	20.55	0.89	17.36	13.31	0.70	14.38
CITH□AP 22	419.33	29.16	35.49	34.90	20.87	2.85	24.51	19.12	1.06	17.59	13.11	0.77	7.91
CITH□AP 23	536.33	26.69	36.83	35.20	17.24	2.71	24.86	19.01	1.04	18.48	13.14	0.67	12.79
CITH□AP 24	421.00	29.54	39.73	39.11	25.78	2.17	22.66	17.73	1.07	16.89	12.41	0.38	9.96
CITH□AP 25	277.67	51.34	44.87	44.27	20.78	3.24	26.13	20.90	1.61	20.61	13.82	0.46	12.56
CITH□AP 27	364.33	31.00	38.11	37.79	15.62	2.63	23.63	19.28	0.92	16.27	11.77	0.50	9.46
CITH□AP 28	523.33	27.13	38.21	37.67	20.05	2.63	23.88	18.70	1.34	15.98	12.23	0.59	10.69
CITH□AP 29	412.67	33.22	42.15	42.58	19.90	2.95	24.66	21.26	1.23	16.05	12.87	0.31	13.14
CITH□AP 30	170.00	37.44	37.31	36.73	15.26	2.58	25.50	21.20	0.91	17.08	12.80	0.54	5.42
CITH□AP 31	240.33	29.39	40.39	37.66	24.45	2.80	26.59	21.46	1.39	15.78	12.16	0.56	7.53
CITH□AP 32	798.33	37.51	43.61	42.72	21.23	2.70	23.19	21.76	1.25	17.86	12.94	0.31	23.49
CITH□AP 36	118.00	25.23	31.47	31.68	19.37	2.18	21.27	18.67	1.19	14.19	11.18	0.48	5.87
CITH□AP 37	380.67	30.70	37.45	36.60	24.92	2.88	23.80	20.65	1.63	18.09	13.95	0.50	9.36
Communis	1253.00	49.74	44.11	47.50	17.49	2.59	23.05	20.58	1.17	15.13	12.77	0.85	43.08
Communis Holy	964.33	32.58	41.49	36.84	17.58	2.34	24.27	18.56	1.02	14.62	11.70	0.80	22.00
Erani	1615.00	64.08	46.54	49.74	16.44	3.74	26.08	23.35	1.72	16.25	14.14	0.51	67.32
Fairmedcester	1316.00	38.32	40.22	38.27	17.26	2.64	24.34	18.36	0.87	17.06	12.66	0.69	29.95
Harcot	997.33	51.73	50.52	43.70	16.09	2.68	27.19	21.36	0.78	16.69	12.55	0.69	43.11
Heartly	1120.67	31.29	39.99	39.94	19.05	2.77	25.17	20.84	0.95	16.65	13.31	0.47	25.82
Nari	318.67	32.12	37.72	40.74	15.15	2.40	21.08	19.16	0.95	14.29	13.10	0.41	6.65
New Castle	1189.00	36.05	34.79	37.64	17.52	2.56	21.03	18.71	1.08	13.76	11.21	0.51	33.34
Rival Apricot	328.67	55.05	48.20	46.53	17.30	2.75	27.12	20.00	1.01	16.65	12.43	0.53	14.15
Tilton Apricot	189.33	39.80	40.23	38.03	16.31	2.98	25.05	19.22	0.98	16.98	12.73	1.03	4.27
Tokpopa Nimu	415.67	55.09	46.19	45.86	19.16	2.95	26.71	19.57	1.17	19.87	12.97	0.88	20.09
Turkey	828.33	37.93	34.81	42.10	17.70	2.88	22.45	19.43	1.12	13.73	11.54	0.34	26.19
Viva Gold	60.00	40.61	42.52	43.54	19.63	2.54	25.07	19.78	0.99	16.32	12.98	0.56	2.26
LSD (P=0.05)	811.37	18.38	6.49	8.76	5.45	0.83	3.12	2.65	N.S	3.06	1.81	N.S	24.74

and 3).

The average weight and dimensions of the fruits were measured as minimum, maximum and average values (Table 2 and 3). The fruit length and diameter was ranged from 31.47 mm to 50.52 mm and 31.68 to 53.89 mm respectively and maximum was recorded in Erani (49.74 mm) followed by CITH-AP 1 (49 mm) and minimum in CITH-AP 36 (31.47 mm) whereas fruit diameter was maximum in CITH-AP 1 (53.89 mm), followed by CITH-AP 2 (53.71 mm) and CITH-AP 3 (49.40) and minimum in CITH-AP 36 (31.68 mm). Fruit weight varied from 19.70 – 81.94 g; wherein, highest fruit weight was recorded in CITH-AP 1 (81.94 g) followed by CITH-AP 2 (70.10 g) and least in CITH-AP 15 (19.70 g). Stone length was ranged from (21.03 -28.54 mm), stone diameter (17.73-24.36 mm) and stone weight (2.17-4.34 g) varied significantly among the germplasm evaluated for the study. The maximum stone diameter and stone weight was recorded in genotype CITH-AP 2 (24.36 and 4.34 mm) followed by CITH-AP 1 (23.69 and 3.71 mm) and it was least in CITH-AP 24 (17.73 and 2.17 mm).

It is a well-known fact that apricot stones are used in genotype identification and have a high utilization value such as kernel oil extraction for food and medicine (Özcan, 2000, Mandal *et al*. 2007). Similarly, kernel weight and diameter ranges from 0.78-1.72 and 10.79 -15.07 with standard deviation 2.29 and 2.06 and coefficient of variation 89.12 and 17.15% respectively. Maximum kernel weight recorded in Erani 1.72 g and least in Afghani (0.78) whereas maximum kernel diameter recorded in CITH-AP 14 (15.07) and least in CITH-AP 6 (10.79). In case of kernel length, maximum was recorded in CITH-AP 25 (20.61) and minimum in CITH-AP 6 (12.96). Similar kind of genetic diversity also have been reported by Asma *et al.* (2007) and Valdés *et al.* (2009) among morpho-physico-chemical traits, probably due to several factors such as geographical distribution, origin, genotypes, climate and their interaction.

The total soluble solids (TSS) ranged from 14.06 to 25.78° Brix and maximum TSS was measured in genotype CITH-AP 24 (25.78 °Brix) followed by CITH-AP 37 (24.92 °Brix), CITH-AP 31 (24.45 °Brix) and least in Chinese Apricot (14.06 °Brix). However, fruit acidity varied from 0.24 to 1.15% and maximum found in CITH-AP 8 (1.15%) followed by CITH-AP 16 (1.05%) and least in CITH-A 19 (0.24%). In generally, it may be concluded that the knowledge of the qualitative and quantitative compositions of acids and sugars in apricot fruits may prove to be a powerful tool in evaluating fruit maturity and quality (Mratinic *et al.* 2011). Akin *et al*. (2008) also reported the wide variability among apricot fruit chemical compositions. These variations among genotypes were likely due to the different eco-geographical groups of apricot genotypes studied and the environmental conditions.

Descriptive statistics revealed the maximum standard deviation was observed for number of fruit per plant (475.40) followed by fruit yield (20.54 kg/plant), fruit weight (13.88 g) and least for acidity (0.214%). Similarly, coefficient of variation was found maximum for fruit yield (96.45 kg/plant) followed by number of fruits/plant (69.59). Skewness describes the symmetrical distribution pattern with respect to its dispersion from the mean. The skewness values showed that the data were normally skewed which were less than +2. However, positive skewness was recorded for number of fruits/plant, fruit length, fruit weight, fruit diameter, TSS, stone length, stone weight, stone diameter, acidity, and fruit yield. Kurtosis tells the weight of the tails of a distribution. These results showed the distribution of quantitative traits which provides information about nature of gene action and number of genes controlling the traits respectively. The skewed distribution of a trait in general suggests that the trait is under the control of non-additive gene action and is influenced by environmental variables. Positive skewness is associated with complementary gene interactions while negative skewness is associated with duplicate (additive × additive) gene interactions. The genes controlling the trait with skewed distribution tend to be predominantly dominant irrespective of whether they have increasing or decreasing effect on the trait.

In the present set of data it was recorded platykurtic distribution pattern for number of fruits/plant, fruit weight, fruit diameter, stone weight, kernel weight and yield/plant

Table 3 Descriptive statistics for thirteen phenological, fruit quality, and yield traits of 49 apricot genotypes

Variable	Range	Mean	Std Dev	CV%	Skewness	Kurtosis	Bimodality
No. of fruits/plant	60-1957.33	683.1	475.4	69.59	1.1249	0.5118	0.6108
Fruit weight (g)	19.70-81.94	39.2043	13.8808	35.41	1.2423	0.9774	0.6093
Fruit length (mm)	31.47-50.52	40.2745	4.5610	11.32	0.4449	-0.6608	0.4723
Fruit diameter (mm)	31.68-53.89	40.6206	5.3089	13.07	0.7463	0.00849	0.4857
TSS (^{0}B)	14.06-25.78	18.7296	2.7209	14.53	0.6611	-0.0891	0.4624
Stone weight (g)	2.17-4.34	2.8480	0.4655	16.34	1.1850	1.1866	0.5485
Stone length (mm)	21.03-28.54	24.4478	1.9756	8.08	0.1785	-0.7304	0.4183
Stone diameter (mm)	17.73-24.36	20.1622	1.6315	8.09	0.7762	-0.1480	0.5256
Kernel weight (g)	0.78-1.72	1.1349	0.2202	19.40	0.7004	0.2120	0.4372
Kernel diameter (mm)	12.96-20.61	16.7667	1.7152	10.23	-0.0198	-0.1458	0.3279
Kernel length (mm)	10.79-15.07	12.9347	0.9363	7.24	-0.0144	-0.1514	0.3284
Acidity (%)	0.24-1.15	0.6322	0.2141	33.87	0.3866	-0.3315	0.4011
Yield/plant (kg)	2.26-110.40	21.2969	20.5411	96.45	2.4180	7.1210	0.6636

however leptokurtic distribution for fruit length, TSS, stone length, stone diameter, kernel diameter and acidity. Kurtosis is negative or close to zero in the absence of gene interaction and is positive in the presence of gene interactions. The traits with leptokurtic and platykurtic distribution are controlled by fewer and large number of genes, respectively.

Bimodality of genetic admixture values provides evidence of strong isolation between two morphological and genetic clusters, supporting the existence of a sympatric genotypes pair within the gene pool. In the present study, values are near to zero, explains the closeness among the genotypes for the traits under study.

The dendrogram classified 49 genotypes in to two major groups at 1.82 NRMS distance (Fig 1). The first group included five genotypes (Afghani, CITH□AP 1, CITH□AP 2, Erani and CITH□AP 3) contributed 10.20% of the total genotypes in this population. It had the highest number of fruits per plant, maximum fruit length, fruit diameter, fruit weight, medium stone length, stone diameter, stone weight, kernel diameter, kernel weight and kernel length, low to medium in acidity, mid to high TSS and maximum fruit yield. The second group comprised of 44 genotypes (Balcota, Chinese Apricot, CITH□AP 4, CITH□AP 5, CITH□AP 6, CITH□AP 7, CITH□AP 8, CITH□AP 9, CITH□AP 10, CITH□AP 11, CITH□AP 12, CITH□AP 13, CITH□AP 14, CITH□AP 15, CITH□AP 16, CITH□AP 17, CITH□AP18, CITH□AP 19, CITH□AP 20, CITH□AP 21, CITH□AP 22, CITH□AP 23, CITH□AP 24, CITH□AP 25, CITH□A 27, CITH□AP 28, CITH□AP 29, CITH□AP 30, CITH□AP 31, CITH□AP 32, CITH□AP 36, CITH□AP 37, Communis, Communis Holy, Fair medcester, Harcot, Heartly, Nari, New Castle, Rival Apricot, Tilton Apricot, Tokpopa Nimu, Turkey and Viva gold) that contributed 89.80% of the total genotypes. This group is further divided in to two major clusters at 0.99 NRMS distance. The first cluster consisted of seven genotypes contributed 14.28% of the total genotypes which is further divided in to two sub clusters at 0.521 NRMS distance in which first sub cluster comprised four genotypes (Balacota, Turkey, CITH□A 9, CITH□AP 32, CITH□AP 7, Communis Holy and Harcot)

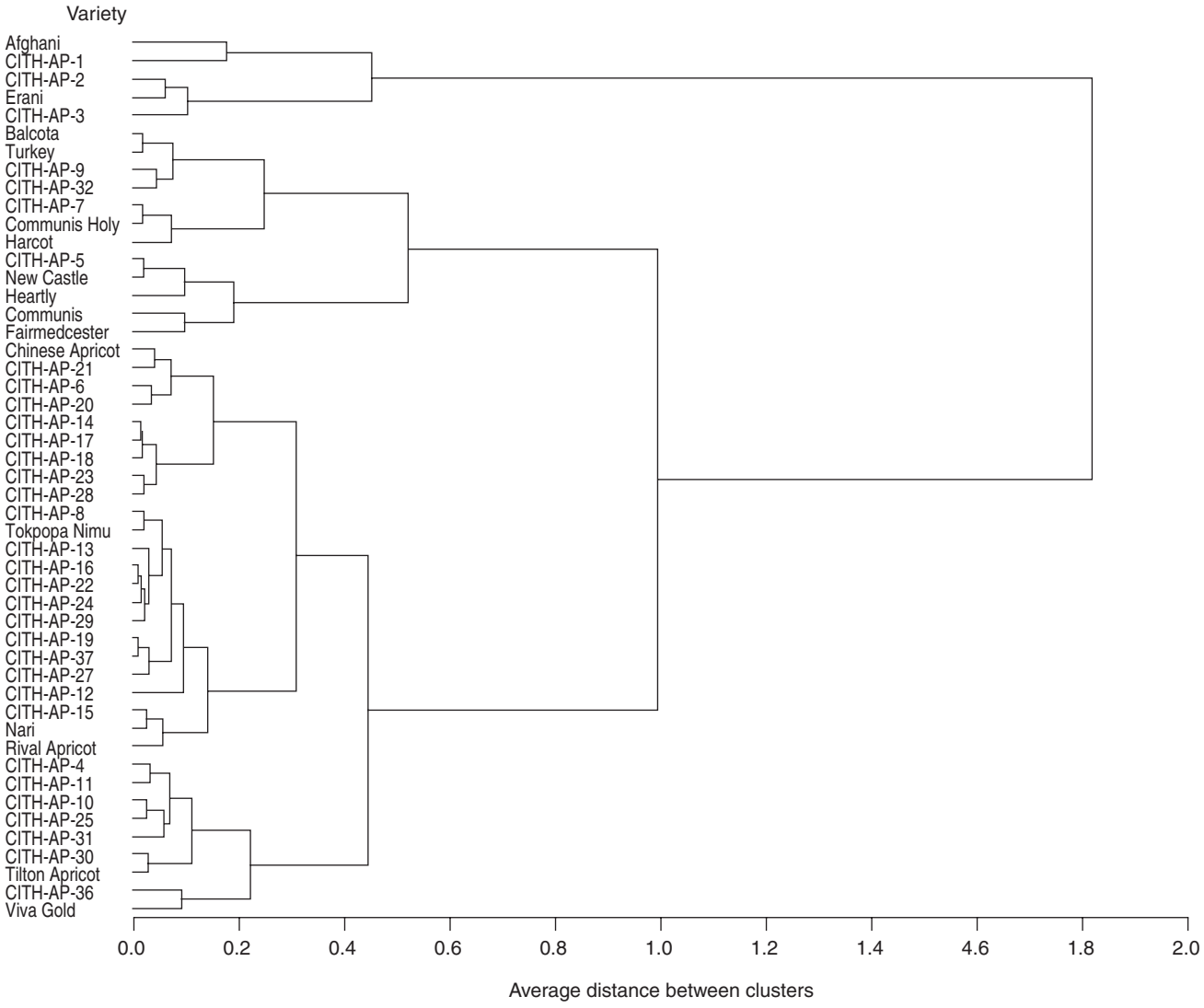

Fig 1 Dendrogram of 49 *Prunus armeniaca* genotypes obtained by average distance between cluster analyses based on 13 phenological, fruit quality, and yield traits

Table 4 Principal component analysis of the apricot genotypes showing the eigen vectors, eigen values and percentage total variance accounted for by the thirteen principal component axes

	Eigen vectors												
	PRIN1	PRIN2	PRIN3	PRIN4	PRIN5	PRIN6	PRIN7	PRIN8	PRIN9	PRIN10	PRIN11	PRIN12	PRIN13
No. of fruits/plant	0.165	−0.482	0.180	0.475	0.182	0.012	0.225	−0.094	−0.209	−0.007	−0.266	0.478	0.216
Fruit weight (g)	0.362	−0.139	−0.088	−0.236	0.005	0.222	−0.133	−0.161	0.310	−0.027	0.590	0.499	−0.021
Fruit length (mm)	0.346	−0.028	−0.128	−0.313	0.260	0.320	0.065	−0.117	−0.359	0.017	−0.319	−0.017	−0.588
Fruit diameter (mm)	0.359	−0.133	0.035	−0.286	−0.063	0.238	−0.216	−0.156	0.220	−0.187	−0.405	−0.283	0.559
TSS (°B)	−0.102	0.333	0.555	0.121	0.303	0.568	−0.009	0.330	0.165	−0.050	0.009	0.055	0.006
Stone weight (g)	0.357	0.093	0.084	0.150	−0.145	−0.358	0.074	0.259	0.531	−0.309	−0.293	0.102	−0.372
Stone length (mm)	0.310	0.237	−0.163	−0.132	0.348	−0.232	0.315	0.368	−0.319	−0.362	0.238	−0.036	0.322
Stone diameter (mm)	0.354	−0.006	0.168	−0.106	−0.209	−0.146	−0.260	0.489	−0.194	0.641	−0.037	0.080	0.086
Kernel weight (g)	0.207	0.220	0.388	−0.060	−0.586	0.083	0.523	−0.281	−0.192	−0.018	0.113	−0.044	0.015
Kernel diameter (mm)	0.199	0.482	−0.150	0.176	0.358	−0.124	0.186	−0.403	0.261	0.488	−0.099	0.005	0.132
Kernel length (mm)	0.249	0.315	0.097	0.418	−0.065	−0.072	−0.613	−0.259	−0.340	−0.266	0.107	−0.025	−0.054
Acidity (%)	0.122	0.077	−0.597	0.436	−0.319	0.488	0.125	0.262	0.031	0.033	−0.002	−0.075	0.037
Yield/plant (kg)	0.274	−0.410	0.182	0.272	0.201	−0.007	0.093	−0.018	0.115	0.114	0.371	−0.642	−0.154

which possessed average fruit bearer, medium fruit length, fruit diameter, fruit weight, stone length, diameter, stone weight, TSS and fruit yield and the second sub-cluster consisted of five genotypes (CITH-AP 5, New Castle, Heartly, Communis and Fairmedcester) having similarity in number of fruits per plant and fruit attributes such as fruit weight, fruit length and TSS.

The second cluster was also further divided into two major sub clusters and segregated at 0.446 NRMS distance comprising 32 genotype which contributes 65.30% of the total genotypes. The first major sub cluster further divided in two sub-sub cluster at 0.310. The first sub-sub cluster consisted of nine genotypes namely Chinese Apricot, CITH-AP 21, CITH-AP 6, CITH-AP 20, CITH-AP 14, CITH-AP 17, CITH-AP 18, CITH-AP 23 and CITH-AP 28 and possessed high stone weight, stone length, stone diameter attributes and second sub-sub cluster comprised of 14 genotypes (CITH-AP 8, Tokpopa Nimu, CITH-AP 13, CITH-AP 16, CITH-AP 22, CITH-AP 24, CITH-AP 29, CITH-AP 19, CITH-AP 37, CITH-AP 27, CITH-AP 12, CITH-AP 15, Nari and Rival Apricot) and characterized by high fruit length, fruit diameter and fruit weight. Similarly, the second major sub cluster divided at a distance 0.222 in to two sub-sub clusters. The first sub-sub cluster consisted of seven genotypes (CITH-AP 4, CITH-AP 11, CITH-AP 10, CITH-AP 25, CITH-AP 31, CITH-AP 30 and Tilton Apricot) characterized by medium yielder however second one consists two genotypes (CITH-AP 36 and Viva Gold) which is characterized by lowest yielder. However, traditional fruit morphological and geographical origin classification could not completely reflect the pedigree relationship among the studied apricot genotypes (Yuan *et al*. 2007, Martínez-Mora *et al.* 2009).

The dissimilarity level in terms of genetic distance ranged from 0.042-1.82 indicating a high degree of dissimilarity between genotypes and high genetic distance between genotypes and if chosen for hybridization program, may give high heterotic F_1s and broad spectrum of variability in segregating generations. Similar results also reported in apricot by Mratinic *et al.* (2011).

Principal components analysis is a way of identifying patterns in data, which expresses data in such a way as to highlight their similarities and differences (Mattos *et al*. 2010, Milosevic *et al.* 2010). Therefore, it was carried out to determine the characters more strongly contributed to the principal components. Principal components analysis reduced the original 13 characters in experiment to three principal components. The first three principal components with eigen values >1 explained 73.44% of variation among 49 accessions (Table 3). Other PCs had eigen values <1 and have not been interpreted.

The first PC, which is the most important component, explained 46.68% of total variation and was positively related to number of fruits per plant, fruit length, fruit diameter, fruit weight, stone length, stone diameter, stone weight, kernel weight, kernel diameter, kernel length and yield/plant and negatively related to acidity in which PC1 is a weighted average of these three components. The PC2 accounted of 16.29% of the total variation and the characters with the greatest weight on this component were kernel weight and kernel length. The PC3 accounted for 10.48% and positively related to number of fruits/plant, TSS and kernel weight. This situation confirms the suitability of using phenology as a basis for selecting parental sources; nevertheless, studies through several years must be conducted before parental selection for a possible plant breeding. The PC analysis provided a simplified classification of the apricot genotypes for collecting and breeding (Table 4).

The biplot axes also showed geometrical distances among the genotypes that reflect similarity among them in terms of variables measured. The first two principal component scores were plotted to aid visualization of accessions grouping. The derived cluster and subgroups

were very similar to those identified from average distance between the cluster analyses. More interesting genotypes were CITH□AP 1 CITH□AP 2, CITH□AP 3, Erani, CITH□AP 36, Afghani and Harcot that were disposed in gaps and are the most promising ones. Genotype CITH□AP 36 was characterized by the smallest fruit length, fruit diameter and CITH□AP 15 was characterized for the smallest fruit weight. Genotype CITH□AP 1 was characterized by the highest fruit length, fruit volume, fruit weight and yield. However, Afghani had the maximum number of fruits per plants, CITH□AP 2 had maximum stone length, stone diameter and stone weight; CITH□AP 19 possessed least acidity, and CITH□AP 36 had highest TSS. So, it can be intended for further utilization for introducing these traits in desired genotypes. Identification and description of the genetic variability available in the genotypes of *Prunus* sp. are preliminary requirements for the exploitation of useful traits in plant breeding.

In present study, the cluster analysis classified genotypes into two major groups and further in clusters according to their potential characteristics. The first group genotypes were superior in terms of fruit yield related traits and second group genotypes in quality attributes. Among genotypes most diverse genotypes were as CITH□AP1, CITH□AP□2, CITH□AP 3, Erani, CITH□AP 36, Afghani and Harcot which could be utilized to begin cross□ing and breeding programs which may results in in□creased in desired traits.

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