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GENETIC VARIABILITY IN PHYSICO-CHEMICAL AND MORPHOLOGICAL TRAITS AMONG SANDY PEAR (*Pyrus pyrifolia* Nakai.) GENOTYPES IN NORTH-WESTERN HIMALAYA

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ABSTRACT

The study was aimed to assess the genetic diversity in sandy pear (*Pyrus pyrifolia* Nakai.) of North-Western Himalayan state of Jammu & Kashmir (India) and to explore and characterize the available genotypes using morphological traits. The genetic variability of 30 sandy pear genotypes collected from the 3 districts of Kashmir were evaluated for various qualitative and quantitative traits. The genotypes showed a considerable genetic diversity and differed significantly for traits like tree, leaf, flower, fruit and yield characters. Fruit weight, fruit firmness, total soluble solids, acidity, juiciness, total sugars, yield and yield efficiency ranged from 21.7-200.4 g, 5.3-9.79 kg cm^{-2}, 9.2-17.0^{o}B, 0.11-0.46%, 32.88-84.05%, 4.50-11.15%, 10.0-805.0 kg $tree^{-1}$ and 0.14-1.72 kg cm^{-2}, respectively, with respective mean values of 68.7±0.78 g, 7.52±0.03 kg cm^{-2}, 12.93±0.08^{o}B, 0.23±0.01%, 64.65 ±0.1%, 7.64±0.06, 177.56±0.46 kg $tree^{-1}$ and 0.57±0.004 kg cm^{-2}. The coefficient of variation was highest for fruit diameter (15.58%), followed by fruit length (10.87%) and lowest for juice content (0.28%), followed by yield (0.45%). Fruit diameter showed a significant positive correlation with fruit length and fruit weight but negative correlation of fruit diameter was observed with TSS, acidity and sugars. Yield of sandy pear genotypes had positive correlation with yield efficiency.

Key words: Clusters, correlation, genetic variability, sandy pear, yield

INTRODUCTION

The pear (*Pyrus* sp.) is a well-known temperate fruit popular throughout the world. Pear belongs to the subfamily Pomoideae and family Rosaceae with basic chromosome number of x = 17. The genus *Pyrus* consists of about 20 species of which half are found in Europe, North Africa and Asia minor; and half in the rest of Asia. These have given rise to two groups of domesticated pears, the soft-fleshed European *Pyrus communis* and the crisp-fleshed Asiatic pears, principally *Pyrus pyrifolia.* The Asian or oriental pears are mainly grown in Tian-Shan and Hindu-Kush mountains eastward to Japan and further divided into five groups that is Ussurian pear, Chinese white pear, Chinese sand pear, Xinjiang pear and Japanese pear. Chinese sand pear (*Pyrus pyrifolia)* is native to China, Japan and Korea. Himalayan region is known for its biological richness and has always been

a botanist's paradise. In India, commercially grown pear cultivars belong to *P. pyrifolia* and *P. communis* groups. The Chinese sand pear (*P. pyrifolia*) is widely grown in North Western Himalayan region including Jammu and Kashmir. In India, the maximum area under the cultivation of Chinese sand pear is in Kashmir valley. Locally known as "Kashmiri Nakh", it is believed one of the naturalized indigenous cultivars grown since ancient time in India (Verma *et al.*, 2014). During last few decades, the number of Kashmiri Nakh trees has decreased because of its long juvenile phase and giant tree size. Therefore, conservation is urgently needed to prevent this species from becoming extinct. Variability in taste and colour of fruits is mostly due to the changes in contents and ratios of sugar (Doyon *et al.*, 1991). Paganova (2003) described variability in fruit shapes as round or apple shaped and ovate to oblong in various pear genotypes. Ahmed *et al.* (2011) maximum fruit weight in MZ26 (Kotharnul) and RT5 (Kortharnul) and these two selections were statistically alike but differed significantly from all other selections. Bhat (2012) reported that variation in tree habit was seen among pear genotypes. The morphological characteristics of fruit in genotypes of *Pyrus* species are variable with respect to their genetics and environments.

The basic information needed for the improvement of a plant species is the nature and magnitude of genetic diversity present in the available germplasm (Bhat and Dhillon, 2015). The conservation and sustainable use of genetic resources is imperative to meet the demand for future food security. However, little efforts have been made for genetic characterization of diversity in sandy pear cultivars in Kashmir valley. The extent of genetic diversity in sandy pear population should encourage breeders to identify and characterize promising genotypes for farmer's adoption. Keeping in view the importance of genetic diversity for effective management, conservation and improvement of sandy pear in Kashmir valley, the present study was aimed to assess the genetic diversity in sandy pear on morphological trait basis and to explore and characterize the available sandy pear genotypes for use in future improvement programmes.

MATERIALS AND METHODS

Germplasm collection in study sites

The present investigation was carried out in pear growing districts of Jammu & Kashmir state *viz.*, Anantnag, Budgam and Kulgam. Ten distinct genotypes were selected at fruit maturity stage from each district and earmarked with durable label (aluminum sheet) during initial survey. The genotypes were selected on the basis of fruit morphological traits (shape, size, colour, etc.) in field during fruit maturity stage. A total of thirty genotypes were selected for their distinct characteristics of horticultural interest for characterization.

Data collection on morphological and physico-chemical traits

The survey was conducted for two years during 2013 and 2014. The observations were recorded as per the International Union for the Protection of New Varieties of Plant Standard Descriptor (UPOV, 2000). Mature fruits of sandy pear were brought to the laboratory, Division of Fruit Science, SKUAST-K, Shalimar for recording various parameters. Five replicates were taken to represent each genotype for quantitative traits such as leaf length, width, petiole length, flower bud length, fruit diameter, fruit size, length of stalk, etc. Qualitative traits including tree branching, tree growth habit, leaf shape, position of margin of petals and incision of margins were determined by careful observation and comparison with UPOV descriptor. The fruits were evaluated for various quality parameters. Fruit texture was evaluated by a panel of 10 members against a scale. Ten fruits of each genotype were presented to the panel. The overall colour of fruits was measured by colour chart. Ten fruits from each genotype were cut into halves and seeds removed from flesh. The total soluble solids were recorded by using a hand refractrometer (model: PR-32α, ATAGO, Tokyo, Japan) at room temperature. The juice of each genotype was extracted by a blender and preserved in

glass beakers separately. The juice was analyzed for juice content, total titrable acidity (as % malic acid), total sugars, reducing and non-reducing sugars as per AOAC (2000). The titrable acidity was determined by titrating a known volume of juice against 0.1 N NaOH solution, using phenol-phthalein as an indicator. Total, reducing and non-reducing sugars were estimated by Lane and Eynon's method (Rangana, 1995). The yield was calculated from the average weight of fruits multiplied by total number of fruits present in each genotype and expressed in kg tree^{-1}. The yield efficiency was calculated by dividing yield of each tree by trunk cross sectional area of the same tree.

Data analysis

The data was subjected to descriptive statistics, analysis of variance, correlation analysis and D^2 analysis for quantitative traits; while frequency distribution was assessed for qualitative traits (Singh and Chaudhary, 1977). The statistical analyses were conducted using IBM SPSS software version 20.

RESULTS AND DISCUSSION

Qualitative traits

Tree and leaf traits: The tree characteristics i.e. tree vigour, tree branching and tree habit were recorded on visual observations during two successive years (2013 and 2014). The summary of frequency of distribution for the parameter is given in Table 1. Out of the 30 genotypes of sandy pear 12 (40%) had medium tree vigour, while 11 genotypes (36.66%) had strong tree vigour and rest 7 genotypes (23.3%) had weak tree vigour. On the basis of tree branching, sandy pear genotypes were divided into four categories i.e., absent/very weak, weak, medium and strong. Out of thirty genotypes studied 21 (70%) had spreading growing habit while 9 (30%), had upright growth habit. Tree characteristics are an important factor for characterizing sandy pear genotypes. However, tree characteristics *viz*., tree vigour, tree branching and tree habit is greatly influenced by the location, soil and different cultural practices like training and pruning. It was observed that those trees which were growing under direct sunlight had vigorous growth and produced good quality fruits as compared to those having dense canopies possibly due to more sunlight available for dry matter production. Shyamali (2006) reported that variation in tree characters of different pear genotypes and these variations might be due to genetic makeup of the pear cultivar/rootstock. Verma *et al*. (2014) studied genetic variability among Kashmiri Nakh pear (*P. pyrifolia*) and reported that tree height ranged from 3.15 to 14.15 m and maximum recorded in genotype CHB-4, followed by TBP- 3 and minimum in TB-3.

Leaf length varied from genotype to genotype and ranged between short, medium and long. Incision of margins of leaves varied between bluntly serrate and sharply serrate. The incisions of margins of leaves were grouped into four categories *viz*., absent, crenate, bluntly serrate and sharply serrate. Leaves play an important role in plant growth and development as leaves are the part of plant which serves as a source of food to the plants. In present study a wide variation has been observed in various leaf characters of sandy pear genotypes. Leaf length, leaf breadth and petiole length varied between short, medium and long. Singh (2006) reported maximum leaf breadth in Strain III and VIII and minimum in Strain XI. Other leaf characteristics which showed divergence among thirty sandy pear genotypes in present study were leaf blade, shape of apex, shape of base and incision of margins. Elshihy *et al*. (2004) have reported serrate leaves in Syrian pear genotypes with leaf index (leaf width/leaf length) ranging from 0.35 to 0.78.

Flower and fruit traits: The trees were observed during blooming period and categorized as early, medium and late bloomers (Table 1). The date of beginning of flowering was early in Kaniyar (Srinagar), Budgam and late in Verinag (Anantnag). The flower buds were present both on spurs as well as on shoots. The 30 genotypes under study were divided into two categories on the basis of the

Table 1: Summary of frequency qualitative traits of 30 sandy pear (*Pyrus pyrifolia*) genotypes collected from three districts of Jammu & Kashmir

Traits	Category	No. of geno-types	% geno-types	Traits	Category	No. of geno-types	% geno-types
Tree vigour	Weak	7	23.33	Date of beginning of flowering	Early (before 13thMarch)	7	23.33
	Medium	12	40.00		Mid (13th to 15thMarch)	18	60.00
	Strong	11	36.66		Late (after 15thMarch)	5	16.66
Tree branching	Weak	5	16.66	Flower bud length (cm)	Short (<0.5)	3	10.00
					Medium (0.5-1.0)	19	63.33
	Medium	12	40.00		Long (>1.0)	8	26.66
	Strong	13	43.33	Sepal length (cm)	Short (<0.5)	3	10.00
Tree habit	Upright	9	30.00		Medium (0.5-1.0)	18	60.00
	Spreading	21	70.00		Long (>1.0)	9	30.00
				Petal length (cm)	Short (<1.0)	0	0.00
Leaf length (cm)	Short (< 7.5)	2	6.66		Medium (1.0-2.0)	10	33.33
	Medium (7.5-10.0)	15	50.00		Long (>2.0)	20	66.66
	Long (> 10.0)	13	43.33	Petal width (cm)	Medium (0.5-2.0)	22	73.33
Leaf width (cm)	Narrow (<5.5)	9	30.00				
	Medium (5.5-6.5)	16	53.33		Long (>2.0)	8	26.66
	Long (> 6.5)	5	16.66	Location of flower buds	Mainly on spurs	30	100.00
Petiole length (cm)	Short (<4.0)	3	10.00				
	Medium (4.0-6.0)	19	63.33	Position of petal margin	Apart	3	10.00
	Long (>6.0)	8	26.66		Touching	8	26.66
Shape of leaf base	Right angled	6	20.00		Overlapping	19	63.33
				Ground colour of fruit	Green	30	100.00
	Obtuse	24	80.00				
Shape of leaf apex	Acute	30	100.00				
				Relative area of over colour	Absent/very small	11	36.66
					Small	14	46.66
Incision of margins	Bluntly serrate	12	40.00		Medium	4	13.33
					Large	1	3.33
				Length of stalk (cm)	Short (<3.0)	3	10.00
	Sharply serrate	18	60.00		Medium (3.0-4.0)	23	76.66
Date of beginning of flowering	Early (before 13thMarch)	7	23.33		Long (>4.0)	4	13.33
	Mid (13th to 15thMarch)	18	60.00	Thickness of stalk (cm)	Thin (<0.3)	13	43.33
	Late (after 15thMarch)	5	16.66		Medium (0.3-0.5)	14	46.66
Flower bud length (cm)	Short (<0.5)	3	10.00		Long (>0.5)	3	10.00
	Medium (0.5-1.0)	19	63.33	Time of beginning of fruit ripening	Early (1st week of Sept.)	7	23.33
	Long (>1.0)	8	26.66		Mid (2nd week of Sept. to last week of Sept.)	18	60.00
					Late (1st week of Oct to 1st week of Nov.)	5	16.66

location of flower bud i.e. mainly on shoots and spur. The location of flower buds was mainly on spurs in all the 30 genotypes (100%) studied. The position of petal margins was divided into 3 categories i.e., apart, touching and overlapping. On the basis of time of flowering initiation, the 30 sandy pear genotypes were categorized as early, medium and late bloomers. Maximum genotypes (18) were found mid bloomers, and minimum genotypes (5) where late bloomers while rest (7) were early bloomers. Our results are in agreement with Ahmed (2008) who reported that the maximum number of genotypes bloomed in mid of flowering season, some were early or early to medium and only a few were late blooming. In present study flowering began first in Budgam district whereas it was last in Verinag (Anantnag). These genotypes varied in their flowering depending upon the prevailing climatic conditions. Variability in flowering beginning may probably

Table 2: Range, mean ± SE, coefficient of variation (%) and mean sum of squares of quantitative traits studied among 30 sandy pear (*Pyrus pyrifolia*) genotypes in Jammu & Kashmir

Traits	Range	Mean ± S.E.	Coefficient of variation (%)	Mean sum squares
Fruit length (cm)	4.00-8.20	5.47±0.49	10.87	2.72**
Fruit diameter (cm)	4.00-9.60	5.53±0.34	15.58	3.64**
Fruit weight (g)	21.70-200.43	68.73±0.78	1.98	4173.61**
Fruit firmness (kg)	5.30-9.79	7.52±0.03	0.69	6.08**
TSS (^{0}B)	9.20-17.00	12.93±0.08	1.17	12.37**
Acidity (% malic acid)	0.11-0.46	0.23±0.01	4.35	0.02**
Juice content (%)	32.88-84.05	64.65±0.10	0.28	592.54**
Total sugars (%)	4.50-11.15	7.64±0.06	1.43	13.53**
Reducing sugars (%)	3.25-7.40	5.43±0.05	1.84	2.98**
Non-reducing sugars (%)	0.30-7.35	2.19±0.09	7.21	9.58**
Yield (kg tree^{-1})	10.0-805.00	177.56±0.46	0.45	85586.8**
Yield efficiency (kg cm^{-2})	0.14-1.72	0.57±0.004	1.22	0.81**

be due to the topography, elevation and mean temperature of the area where the genotypes were growing. Bhat (2012) reported that the data of different pear genotypes related to initiation of flowering period showed a significant variation. He further reported that variability in flowering time among different pear genotypes may be attributed to the difference in chilling hours required for breaking flower bud dormancy.

Relative area of over-colour of fruits of collected genotypes was recorded with the help of a colour chart. The genotypes were categorized into four major groups on the basis of relative area of over-colour which were differentiated visually. It was observed that maximum genotypes didn't show any over-colour whereas only one genotype showed a large area of over-colour. Fruit colour is a very important character for assessing the quality and maturity of fruits and is significantly influenced by temperature, location of plant, light penetration and growth habit of tree. Sunlight is main factor responsible for the synthesis of anthocyanin in fruit skin (Erez and Flore, 1986) and thus fruit colour (Marini *et al.*, 1991). The length of stalk of 30 sandy pear genotypes varied between short, medium and long. Variation in length and thickness of pedicel has been observed by various other workers (Singh 2002, Shyamali, 2006; Bhat, 2012). In present study the beginning of fruit ripening was evaluated on the basis of fruit size, change in colour, firmness and overall visual observations. The fruit ripening is influenced by both genetic and environmental factors. It was observed that the genetic diversity not only existed in morphological traits but also in ripening time.

The yield of pear genotypes depends upon initial fruit set, its retention and subsequent fruit growth and development which is influenced by prevailing environmental conditions. Based on fruit bearing the sandy pear genotypes were grouped into three categories i.e., regular, irregular and biennial. In present study 11 (36.66%) genotypes had medium, 10 (33.33%) had light and 9 (30%) had heavy cropping of fruits. Yield efficiency and yield (kg tree^{-1}) varied among all the 30 genotypes of sandy pear (Table 1). Highest yield efficiency of (1.72 kg cm^{-2}) was recorded in Ang-P-11 and lowest yield efficiency of 0.14 (kg cm^{-2}) in genotypes Bud-P-9, Ang-P-16, Kul-P-23 and Kul-P-27. Reighard *et al.* (2008) found that cumulative yield efficiency (kg cm^{-2}) was significantly different among pear cultivars with Atago being more than twice as yield efficient as Hosui. Variability in yield may be attributed to several factors like differences in the number of blossoms, final fruit set, fruit number, fruit size, tree size. Variations in fruit yield for different pear genotypes were reported by Sandhu *et al.* (2007).

Quantitative traits

The magnitude of variability present in various quantitative traits under study revealed existence of wide range of variability for all the traits. The variability parameters *viz.*, mean, range and coefficient of variation are presented in Table 2. It revealed that the fruit weight ranged from 21.70-200.43 g with the mean of 68.73±0.78 g, fruit firmness ranged from 5.30-9.79 kg cm^{-2} with mean of

Table 3: Mean values of fruit characteristics (descriptive) of 30 sandy pear (*Pyrus pyrifolia*) genotypes

Genotypes	Fruit diameter (cm)	Fruit length (cm)	Fruit weight (g)	Yield (kg tree^{-1})	Yield efficiency (kg cm^{-2})
Bud-P-1	4.00±0.28	4.30±0.17	21.70±0.57	10.00±0.28	0.24±0.01
Bud-P-2	4.80±0.28	4.80±0.20	40.25±0.14	13.00±0.28	0.23±0.01
Bud-P-3	9.60±0.57	8.20±0.11	200.43±0.57	172.00±0.28	1.43±0.01
Bud-P- 4	5.60±0.57	6.00±0.57	91.17±0.57	805.00±0.57	1.21±0.00
Bud-P- 5	5.30±0.57	5.70±0.40	65.53±1.15	250.00±0.50	1.08±0.01
Bud-P- 6	5.00±0.28	4.90±0.00	44.45±1.00	62.00±0.28	1.44±0.00
Bud-P- 7	6.60±0.34	6.60±0.57	105.00±1.15	205.00±0.28	0.83±0.00
Bud-P- 8	5.60±0.34	5.90±0.00	85.66±1.15	61.00±0.50	0.97±0.00
Bud-P- 9	4.90±0.57	4.90±0.05	41.90±0.57	400.00±0.28	0.14±0.00
Bud-P-10	5.15±0.08	5.30±0.51	55.26±0.57	110.00±0.50	0.16±0.01
Ang-P-11	4.75±1.15	4.50±0.28	36.45±0.57	111.00±0.28	1.72±0.00
Ang-P-12	4.80±0.57	4.80±0.57	40.25±0.57	71.00±0.50	1.31±0.00
Ang-P-13	4.40±0.57	4.50±0.28	30.67±1.15	172.00±0.57	0.17±0.01
Ang-P-14	4.70±0.57	4.50±0.00	36.45±1.15	41.00±0.57	0.14±0.00
Ang-P-15	7.40±0.34	7.40±0.23	120.00±1.00	202.00±0.57	0.15 ±0.01
Ang-P-16	5.70±0.28	6.50±0.57	102.44±0.57	60.00±0.57	0.26±0.00
Ang-P-17	5.00±0.00	5.10±0.05	49.00±0.57	101.00±0.57	0.17±0.01
Ang-P-18	5.10±1.15	5.30±0.17	55.26±0.57	30.00±0.28	0.48±0.00
Ang-P-19	5.10±0.60	5.30±0.57	52.00±1.15	73.00±0.28	1.17±0.01
Ang-P-20	4.80±0.57	4.80±0.57	40.25±0.00	105.00±0.57	0.17±0.01
Kul-P-21	5.10±0.05	5.40±0.23	56.43±1.15	140.00±0.57	0.16±0.00
Kul-P-22	5.60±0.57	6.00±0.00	87.06±0.57	183.00±0.57	0.16±0.00
Kul-P-23	5.60±0.05	6.10±0.05	91.73±0.57	250.00±0.28	0.14±0.01
Kul-P-24	5.10±0.05	5.50±0.57	60.01±0.57	155.00±0.28	0.21±0.00
Kul-P-25	5.40±0.05	5.80±0.30	83.46±0.57	300.00±0.57	0.18±0.00
Kul-P-26	7.40±0.72	7.20±0.11	115.50±0.57	35.00±0.57	0.31±0.00
Kul-P-27	6.70±0.05	6.80±0.05	109.87±0.57	400.00±0.50	0.14±0.00
Kul-P-28	4.90±0.05	4.90±0.05	41.90±0.57	170.00±0.28	0.17±0.01
Kul-P-29	5.10±0.00	5.20±0.11	52.50±1.15	116.00±0.57	1.17±0.01
Kul-P-30	5.10±0.10	5.20±0.57	49.00±0.57	505.00±0.50	0.92±0.00
Mean ±SE	5.47±0.49	5.53±0.34	68.73±0.78	0.23±0.01	0.57±0.01
$CD_{0.05}$	1.39	0.98	2.23	0.01	0.01
CV (%)	15.58	10.87	1.98	4.35	1.22

Bud-P = pear from Budgam, Ang- P = pear from Anantnag, and Kul-P = pear from Kulgam district

7.52±0.03 kg cm^{-2}, total soluble solids (TSS) ranged from 9.20-17.00^{o}B with the mean of 12.93±0.08 ^{o}B, total sugars, reducing and non-reducing sugars ranged from 4.50-11.15, 3.25-7.40 and 0.30-7.35% with the mean of 7.64±0.06, 5.43±0.05 and 2.19±0.09%, respectively, and yield efficiency ranged

Table 4: Correlation matrix of ten quantitative traits assessed in 30 sandy pear genotypes

Traits	Fruit diameter	Fruit length	Fruit weight	Fruit firmness	TSS	Titrable acidity	Juice content	Total sugars	Yield	Yield efficiency
Fruit diameter (cm)	-	0.71**	0.81**	0.47	-0.10	-0.15	0.07	-0.06	0.11	0.12
Fruit length (cm)		-	0.84**	0.09	-0.18	-0.05	0.14	-0.01	0.18	0.02
Fruit weight (g)			-	0.07	-0.15	-0.15	0.29	-0.-07	0.20	0.10
Fruit firmness (kg)				-	0.08	0.23*	0.09	-0.16	0.06	0.15
TSS (^{0}B)					-	0.31*	-0.20*	-0.48**	-0.08	0.21*
Titrable acidity (%)						-	-0.02	-0.26*	-0.04	-0.19
Juice content (%)							-	0.35**	0.15	0.04
Total sugars (%)								-	0.03	-0.44**
Yield per tree (kg)									-	0.09
Yield efficiency (kg cm^{-2})										-

** Correlation is significant at 0.01 level; * Correlation is significant at 0.05 level

Table 5: Distribution of different selections into clusters based on D^2 statistics

Cluster	No. of genotypes in clusters	Genotype selections
I	17	Bud-P-1, Bud-P-2, Bud-P-13, Ang-P-20, Kul-P-27, Ang-P-18, Kul-P 26, Ang- P-15, Kul-P 21, Kul-P 22, Ang-P-16, Kul-P 23, Kul-P 25, Kul-P 24, Ang-P-17, Kul-P 28 and Ang-P-14
II	2	Bud-P-9 and Bud-P-10
III	9	Bud-P-4, Bud-P-5, Kul-P 29, Kul-P 30, Ang-P-12, Ang-P-19, Ang-P-17, Bud-P-3 and Bud-P-6
IV	1	Bud-P-8
V	1	Ang-P-11

from 0.14-1.72 kg cm^{-2} with the mean of 0.57±0.004 kg cm^{-2}. Coefficient of variation was highest for fruit diameter (15.58%), followed by fruit length (10.87%) and the coefficient of variation was lowest (0.28%) for juice content. The mean values of fruit traits are presented in Table 3. Ahmed *et al.* (2011) reported that higher the coefficient of variation greater would be the variability. In other-words when the coefficient of variation is high, the sample is more variable and when it is low the sample is less variable. Earlier studies conducted in India have revealed the existence of genetic diversity for vegetative, reproductive and yield parameters in pear germplasm of Asiatic and European origin (Verma *et al.*, 2006; Kumar *et al.*, 2010; Rana *et al.*, 2015).

The correlations among different traits like fruit diameter, fruit length and fruit weight were positive (Table 4) indicating that weight of fruits depended on fruit length and diameter. TSS showed showed a negative correlation with all the three fruit traits indicating that the reduced TSS in larger fruits might be as a result of higher water content. Correlations are important in plant breeding because they measure the degree of association between two or more traits and give the indication of traits that could be useful in a particular genotype programme. Bhat (2012) reported that the existence of interrelations among characters is of utmost significance which otherwise are very difficult, and in some crops impossible, to identify due to the segregation.

The dendrogram of 30 selections was constructed based on morphological data in order to examine the variability in sandy pear (Fig. 1, Table 5). Cluster I contained maximum number of selections which comprised of selections Bud-P-1, Bud-P-2, Bud-P-13, Ang-P-20, Kul-P-27, Ang-P-18, Kul-P-26, Ang-P-15, Bud-P-21, Bud-P-22, Ang-P-16, Kul-P-23, Kul-P-25, Kul-P-24, Ang-P-17, Kul-P-28 and Ang-P-14. The cluster II consisted of 2 selections (Bud-P-9 and Bud-P-10), while cluster III consisted of 9 selections (Bud-P-4, Bud-P-5, Kul-P-29, Kul-P-30, Ang-P-12, Ang-P-19, Ang-P-17, Bud-P-3 and Bud-P-6) and cluster IV and V with one selection in each cluster (Bud-P-8 and Ang-P-11, respectively). The populations over the time differentiate due to human selection and genetic drift, and subsequently the alleles showing higher fitness and expression in specific agro-ecosystem lead to divergence (Glaszman, 1990). The grouping pattern of genotypes based on pomological and yield attributes confirmed the results of cluster analysis and that the crosses involving parents belonging to maximum divergent clusters were expected to manifest maximum heterosis and also wide variability in genetic architecture (Verma *et al.*, 2014).

For identification of diverse and desirable selections in terms of intra-cluster distances and performance of clusters for various traits, non-hierarchical cluster analysis was performed (Table 6).

Table 6: Average inter-cluster (above diagonal) and intra-cluster (diagonal) distance values among sandy pear (*Pyrus pyrifolia*)

	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V
Cluster I	3709.17	11411.23	12630.73	13008.00	30803.00
Cluster II	-	456.31	27601.07	7821.63	22746.79
Cluster III	-	-	5270.18	11433.52	17120.32
Cluster IV	-	-	-	-	7084.26
Cluster V	-	-	-	-	-

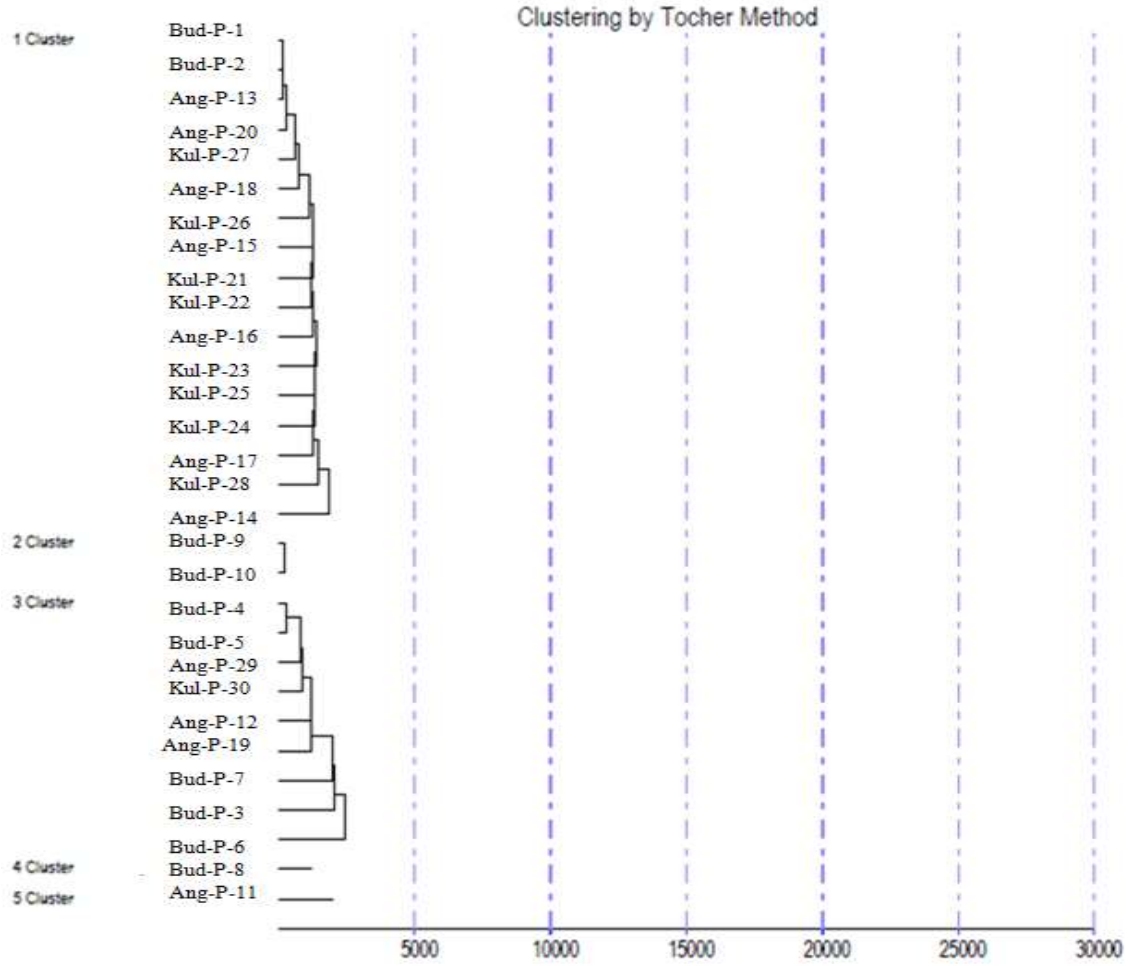

Fig. 1: Dendrogram based on morphological traits of 30 sandy pear (*Pyrus pyrifolia*)

The intra-cluster distances ranged from 0 (cluster IV and cluster V) to 5270 (cluster III). The members of cluster I and V exhibited maximum divergence with inter-cluster distances. The inter-cluster distances were larger than intra-cluster distances indicating a wider genetic diversity between selections of clusters with respect to the trait considered. Maximum inter-cluster distance indicated that the genotypes falling in these clusters had wide diversity and can be used in hybridization programme to get better recombinants in the segregating generations.

The cluster mean values for different traits indicated considerable differences for all the traits among clusters (Table 7). Cluster means of different characters help in choosing the diverse parents for hybridization and these divergent parents are likely to broaden the genetic base and make available transgressive segregants with high heterotic effects (Rao and Gomathinayagam, 1997).

Table 7: Cluster means for various traits in different clusters of pear (*Pyrus pyrifolia* Nakai.)

Clusters	Fruit diameter (cm)	Fruit length (cm)	Fruit weight (g)	Fruit firmness (kg cm^{-2})	TSS (^{o}B)	Titrable acidity (%)	Juice content (%)	Total sugars (%)	Reducing sugars (%)	Non-reducing (%)	Yield efficiency (kg cm^{-2})
I	5.39	5.55	67.24	7.39	12.53	0.24	68.28	8.61	5.87	2.71	0.21
II	5.03	5.10	48.58	6.99	15.33	0.24	35.52	5.88	4.65	1.23	0.15
III	5.80	5.66	77.81	8.15	13.27	0.22	69.70	6.69	4.84	1.84	1.18
IV	5.60	5.90	85.66	7.09	9.85	0.16	43.15	5.30	4.95	0.35	0.97
V	4.75	4.50	36.45	5.74	15.25	0.25	37.35	5.70	5.40	0.32	1.73

Sardana *et al*. (1997) observed that cluster means and genotypic coefficient of variation reveal interesting picture about nature of diversity.

Conclusion: On the basis of comparative evaluation some promising genotypes were identified which can be used as better parents for hybridization for efficient breeding programme. The findings of this research will provide way forward to conduct DUS testing in new varieties for protection under Protection of Plant Varieties and Farmers Right Act (PPV & FRA).

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