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Genetic diversity in antioxidant potential and stomatal behaviour of peach in Central Himalayan Region

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Abstract

To harness the genetic diversity of peach (*Prunus persica*) available in Central Himalayan Region (CHR) 17 accessions, having distinct traits of horticultural importance, were collected and conserved in field gene bank during the last 20 years. Collected germplasm were evaluated for diversity in vegetative and flowering characters viz., leaf length (8.84-19.28 cm), leaf width (2.69-4.33 cm), petiole length (0.78-1.17 cm), tree height (141.73-305.25 cm), canopy area (28296.75-357966.44 cm^2), days to bud break (37.67-74.79), days to end bud break (49.67-80.83), number of flowers per plant (54.77-848.25), flower diameter (2.08-4.25 cm) as well as fruiting traits viz., fruit length (3.38-6.73 cm), fruit width (3.46-6.04 cm), fruit weight (29.30-360.00g), fruit volume (13.95-200.00 cc), stone length (2.15-4.44 cm), stone width (1.27-2.73 cm), stone weight (11.33-71.25g), pulp stone ratio (38.00-142.50), total soluble solids (TSS) (8.50-12.33 ^{0}Brix). Moreover, vitamin 'C' content (6.12-12.26 mg $100g^{-1}$ f.wt.), carotenoids (69-170 g 100^{-1} f.wt.), total phenols (72.1-132.2 mg $100g^{-1}$ f.wt.) and ferric reducing antioxidant power (FRAP) (79.5-137.19 mg of ascorbic acid equivalent assay) of ripe fruits was estimated. In order to find out suitable accessions for water stress and elevated temperature condition leaf samples were collected from field gene bank as well as from locations of germplasm collection and studied for variability in stomatal size (66-111 m at native places and 78-118 m in the field gene bank) and frequency (184-396 at native places and 174-351 in the field gene bank). Fairly rich diversity was found in parameters under study which might be utilized in research, crop improvement programme as well as for cultivation.

Key words

Flowering, Fruit size, Phenols, Stomata, Total soluble solids

Introduction

Prunus persica, commonly known as peach, Batsch is a fruit tree of rose family (Rosaceae), native to North–West China, grown throughout the warmer temperate regions. Peach was first domesticated and cultivated between the Tarim basin and north slopes of the Kunlun Shan mountains in China (Faust and Timon, 2010) since early days of Chinese culture, circa 2000 BC (Singh *et al.*, 2007). It is considered as the queen of temperate-zone fruits and one of the world's most widely grown fruit tree. It is a species well adapted to temperate and subtropical regions, between 30º and 45º North and South latitudes. Peach was brought to India and Western Asia during ancient times. It is a deciduous plant which drops its leaves in winter. As winter progresses, peach trees goes to rest. Exposure to chilling temperature is necessary to overcome the period of rest. After chilling requirement is fulfilled, buds break and growth takes place. Planting a low-chilling accession in a high-chill region risks loss of harvest when an early bloom is hit by a spring frost. Conversely, a high-chilling accession planted in a low-chill region will possibly never fruit. Chilling requirements are expressed as the accumulated daily temperature below some threshold level. To grow and produce economic yield in regions with seasonally freezing temperatures, plants must acclimate to cold weather otherwise they will be subjected to frost and chilling injury. Moreover, at lower altitudes or in areas where winter season is brief, low chilling accessions are suitable. The understanding of plant responses to environmental conditions is crucial for plant behaviour in climate change perspective. Plant growth and development are strongly influenced by perception of signals from the environment (Soares-Cordeiro *et al*., 2010). As a consequence of global warming, plant species are shifting towards cooler regions or higher elevations to get proper chilling. Hence, a relationship of plant parts like stomata with chilling requirement might be crucial for selection of suitable accession.

In the past few years there has been an increasing interest in quantifying antioxidants and phenolic metabolites of fruits due to their health-promoting properties. Phenolic compounds are responsible for many health benefits related to cancer prevention and cardiovascular health (Zhou *et al*., 2004). Contribution of phenolic compounds to antioxidant activity is more important than contribution of vitamin 'C' or carotenoids (Chun *et al*., 2003). Hence, if all three are estimated, relative contribution of phenolic compounds, vitamin 'C' and carotenoids in antioxidant potential becomes obvious and accessions rich in these compounds may be used as parental lines in breeding programme. Furthermore, stomata, small pores on leaf surface, are site of environmental signal perception. Regulation of stomatal conductance is the basic mechanism by which plants control gas exchange and leaf temperature (Salleo *et al*., 2000). With change in climate and altitudinal variation plants adjust stomatal traits like size and frequency (Trivedi *et al*., 2011) to regulate stomatal conductance. Therefore, the present study was conducted with the aim to evaluate diversity in vegetative characters, flowering and fruiting traits, antioxidant potential and stomatal behaviour of peach germplasm of Central Himalayan Region.

Materials and Methods

Present investigation was conducted at National Bureau of Plant Genetic Resources, Regional Station Bhowali, Nainital, Uttarakhand (India), located at an altitude of 1480 m above sea level. The annual precipitation average over last the 10 years has been 1200–1800 mm. The soil was sandy loam with medium organic matter content and pebbles in plenty. Seventeen accessions of peach were collected from altitude ranging from 1,610–2,220 m in peach growing areas of Central Himalayan Region (Fig. 1) were established in the field gene bank in the year 2004 and grown with regular cultural practices.

The study was conducted for three consecutive years, 2011-2013. Leaf length, leaf width and petiole length of fourth fully expanded leaf of a twig from east, west, north and south each were recorded. Tree height from base of the trunk to the top and canopy area (east-west and north-south spread of the plant) was measured before plants entered winter rest. Number of days from Julian day to first bud burst and end of bud burst were counted and expressed as days to bud break and days to end bud break. Number of flowers per plant was counted when plants were at the full bloom stage. Diameters of flowers from east, west, north and south each was measured and the average was expressed as flower diameter.

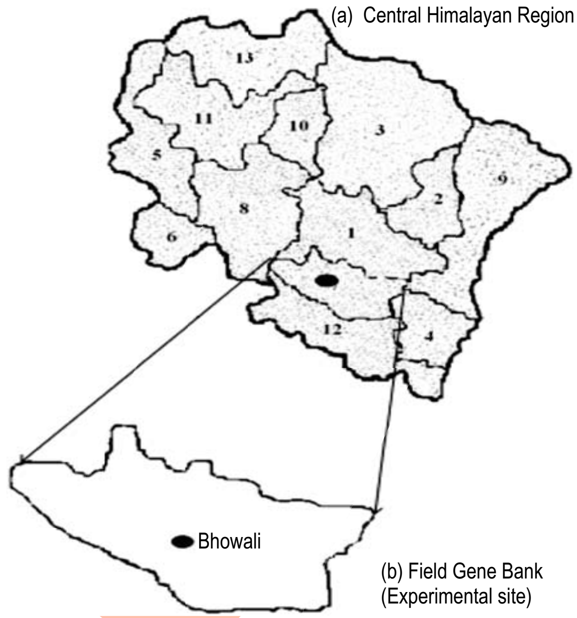

Fig. 1 : (a) Central Himalayan Region i.e., Uttarakhand (distribution map) (b) NBPGR, Regional Station Bhowali i.e., location of experimental site

Length and width of fruits was measured in centimetres. Electronic pan balance was used to record weight of fruits from east, west, north and south each and average is expressed as fruit weight (g). Fruits were dipped in measuring cylinder filled with water, the volume of water replaced by dipping the fruit was recorded as fruit volume. Similarly, length, width and weight of stone were recorded after removing flesh and cleaning the stone. Fruit weight minus stone weight was divided by stone weight to calculate pulp stone ratio. Total soluble solids in fully mature (ready to eat) fruits were calculated by refractometer.

Stomatal size and frequency in leaves of peach accessions present in the field gene bank as well as at locations from where these accessions were collected was measured in the summer of 2011, 2012 and 2013. For stomatal counting, the fourth fully expanded young leaf located at the tip of two branches, facing two different directions (south and north) per tree, were collected and readings from the abaxial side of the leaves were recorded. The epidermis layer of the abaxial side of leaf was painted with clear fingernail polish and a piece of transparency sheet (2 cm^2) was pressed on it by fingers. Later, the imprints of stomata were obtained by striping the transparency sheet from leaves (Schechter *et al*., 1992). Two imprints were taken from each side of the main vein of a leaf (total four imprints per leaf). By using a light microscope with 40 × 10 magnification in a 0.18 mm^2 vision field, stomata were counted on

Table 1 : Values of vegetative and flowering characters of seventeen peach accessions of Central Himalayan Region

IC numbers	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Tree height (cm)	Canopy area plant^{-1} (cm^2)	Days to bud break	Days to end bud break	No. of flowers plant^{-1}	Flower diameter (cm)
IC360682	15.79±0.91	3.84±0.26	1.12±0.071	276.74±7.24	131724.50±289.50	53.13±3.21	61.25±3.47	150.63±5.02	3.80±0.23
IC360683	15.83±0.88	3.73±0.21	1.14±0.073*	226.92±6.32	107251.00±235.72	57.63±3.32	65.13±3.41	207.25±7.33	3.94±0.21*
IC360684	15.49±0.93	3.84±0.23	1.09±0.074	141.73±6.58	28296.75±62.20	62.75±3.41	68.63±3.53	343.88±8.43	3.39±0.26
IC360685	15.55±0.94	3.72±0.22	1.06±0.077	206.88±9.36	88964.00±195.53	67.25±3.29	73.50±3.81	163.50±5.64	2.38±0.19
IC360698	15.86±0.86	4.33±0.28*	1.17±0.073*	188.70±7.48	94470.50±207.63	65.50±3.31	80.00±3.84*	179.13±4.63	2.08±0.21
IC360689	15.57±0.81	3.74±0.25	0.93±0.069	196.24±8.04	74293.13±163.28	58.13±3.39	67.00±3.53	282.38±7.34	4.25±0.29*
IC360690	16.24±0.85*	4.20±0.27*	1.06±0.074	233.25±8.26	137689.00±302.61	68.50±3.48*	74.63±3.61	259.25±6.89	2.28±0.22
IC360691	15.58±0.97	3.59±0.23	1.00±0.068	219.41±9.26	85806.25±188.59	58.25±3.35	68.50±3.62	480.13±8.12	3.49±0.26
IC360695	14.01±0.82	3.64±0.24	0.97±0.072	284.39±5.67*	94676.00±208.10	37.67±3.37	49.67±3.14	179.38±5.13	3.35±0.25
IC247431	15.46±0.83	4.21±0.29*	1.07±0.071	260.83±6.63	120076.67±263.91	68.83±3.42*	74.00±3.49	326.17±6.23	2.13±0.21
IC247432	14.81±0.94	3.77±0.22	1.13±0.073*	160.83±5.49	31616.67±69.49	64.00±3.37	71.00±3.53	137.17±3.89	2.56±0.24
IC320194	19.28±0.99*	3.11±0.21	1.07±0.071	196.67±6.21	76425.00±167.97	65.30±3.24	75.67±3.73	263.83±5.72	2.63±0.26
IC360680	14.76±0.81	3.39±0.23	0.99±0.067	215.83±7.26	67954.42±149.35	59.06±3.18	67.75±3.32	232.94±4.86	4.01±0.29*
IC247430	14.83±0.79	3.48±0.26	1.10±0.076	230.22±6.58	72283.11±158.87	59.53±3.23	68.17±3.38	848.25±7.84*	4.13±0.31*
IC320193	14.03±0.84	3.49±0.25	1.10±0.077	305.25±8.46*	357966.44±787.72*	74.79±3.57*	80.71±3.86*	73.04±3.61	3.38±0.25
IC380693	14.95±0.82	3.56±0.26	1.10±0.076	282.64±6.34*	130666.67±286.18	74.46±3.52*	80.83±3.88*	54.77±2.87	2.96±0.27
IC247433	8.84±0.81	2.69±0.17	0.78±0.066	184.17±5.14	40433.33±88.86	55.38±3.23	63.75±3.47	541.50±7.95*	2.84±0.24

Values given in the table are mean ± SE; * Significant at $p \leq 0.05$

Table 2 : Values of fruiting traits of seventeen peach accessions of Central Himalayan Region

IC Numbers	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Fruit volume (cc)	Stone length (cm)	Stone width (cm)	Stone weight (g)	Pulp stone ratio	TSS (ºBrix)
IC360682	5.99±0.28	5.25±0.25	121.29±3.47	54.17±2.56	3.83±0.26	2.44±0.17	43.75±2.08	85.00±3.14	9.00±0.39
IC360683	6.06±0.31	5.93±0.28*	148.33±4.24	90.50±4.31	3.84±0.27	2.35±0.16	71.25±3.40*	101.25±3.74	9.17±0.38
IC360684	5.96±0.29	5.25±0.26	194.67±5.57	61.42±2.91	3.52±0.25	2.32±0.16	35.20±1.68	53.33±1.96	9.50±0.41
IC360685	5.73±0.28	5.06±0.24	130.23±3.71	62.17±2.97	3.49±0.23	2.31±0.15	46.17±2.21	70.00±2.59	10.88±0.47
IC360698	5.17±0.25	5.60±0.27	43.50±1.24	176.00±8.39*	3.34±0.22	2.25±0.15	43.30±2.06	105.00±3.87	10.50±0.46
IC360689	5.41±0.27	4.87±0.23	213.31±6.10	70.82±3.37	3.78±0.28	2.40±0.17	33.47±1.59	70.00±2.58	11.50±0.51*
IC360690	6.73±0.34*	5.82±0.28*	106.63±3.05	121.50±5.76	3.35±0.21	2.32±0.15	25.00±1.21	92.08±3.42	10.25±0.45
IC360691	5.37±0.27	4.94±0.24	222.25±6.32	61.90±2.95	3.68±0.26	2.37±0.17	45.20±2.16	71.67±2.64	12.13±0.53*
IC360695	5.82±0.29	6.04±0.29*	286.67±8.20*	67.93±3.24	3.49±0.25	2.63±0.18*	49.80±2.38*	120.20±4.46	10.50±0.46
IC247431	6.39±0.32*	5.23±0.25	117.00±3.35	200.00±9.24*	4.12±0.30*	2.41±0.17	44.60±2.13	114.49±4.25	8.50±0.37
IC247432	7.02±0.35*	5.75±0.27	360.00±9.24*	47.75±2.26	4.44±0.32*	2.31±0.16	40.00±1.91	133.13±4.94*	11.50±0.52*
IC320194	6.18±0.31	5.52±0.26	33.35±0.97	50.10±2.34	4.00±0.29*	2.46±0.17	35.00±1.68	142.50±5.28*	12.00±0.51*
IC360680	5.04±0.25	4.52±0.22	192.66±5.46	63.03±3.06	3.69±0.26	2.39±0.18	29.30±1.41	88.75±3.29	11.06±0.48
IC247430	5.36±0.27	5.00±0.24	207.96±5.89	15.93±0.77	3.57±0.26	2.73±0.19*	31.02±1.48	70.00±2.58	11.00±0.47
IC320193	4.81±0.25	4.87±0.23	167.50±4.72	60.72±2.91	3.24±0.23	1.27±0.09	28.53±1.36	98.33±3.65	12.17±0.53*
IC380693	5.16±0.26	5.36±0.26	217.17±6.05	13.95±0.67	3.31±0.24	1.63±0.12	31.84±1.53	83.33±3.11	12.33±0.54*
IC247433	3.38±0.17	3.46±0.16	29.30±0.84	17.10±0.82	2.15±0.15	1.58±0.12	11.33±0.57	38.00±1.41	11.50±0.52*

Values given in the table are mean ± SE; * Significant at $p \leq 0.05$

transparent sheets that were placed on a glass slide. The obtained values were calculated as stomata numbers per mm^2. The counting was replicated on two trees for each accession. Guard cell length (the size of stomata) was measured on 15 different stomata for each leaf sample. Objectives of 20x and 40x (depending on the size and density of stomata) were used in conjunction with a 5x ocular.

Total carotenoid content in fruit pulp was estimated following the method of Talcott and Howard (1999). Ascorbic acid was estimated by spectrophotometric method using diclhorophenol indophenol dye solution (Robinson and Stotz, 1945). Total phenol content was estimated by spectrophotometric method using folin ciocalteu reagent (FCR) method (Singleton and Rossi, 1965). Ferric reducing antioxidant power (FRAP) assay was done by measuring the change in absorbance at 593 nm due to reduction of ferric tripyridyltriazine (Fe^{III}- TPTZ) complex to ferrous form (Benzie and Strain, 1996). Data for each parameter were evaluated for statistical significance using two-way analysis of variance (ANOVA) to compare the means, considering accession and altitude as independent variables. Variation between two groups was assessed by computation of least significant difference taking, 't' values for error d.f. at 5% level of significance.

Results and Discussion

Diverse gene pool is essential for successful cultivation of any crop/ fruit which ought to be maintained through germplasm exploration and collection missions. Diversity in vegetative, flowering and fruiting traits is of prime importance to farmers as well as researchers for selection of germplasm material for research and crop improvement. It is evident that leaf length varied from 8.84 cm in IC247433 to 19.28 cm in IC320194, leaf width varied from 2.69 cm in IC247433 to 4.33 cm in IC 360698 and variability in petiole length ranged from 0.78 cm in IC247433 to 1.17 cm in IC360698. Similarly, tree height ranged from 141.73 cm in IC360684 to 305.25 cm in IC320193. Diversity in canopy area ranged from 28296.75 cm^2 in IC360684 to 357966.44 cm^2 in IC320193. Days to bud break varied from 37.67 in IC360695 to 74.79 in IC320193, while days to end bud break ranged from 49.67 in IC360695 to 80.83 in IC360693 (Table 1). Besides diversity in morphological traits, time of bud break and end bud break was crucial for consumers as well as industry in order to maintain supply for a longer period of time (Martínez-Calvo *et al*., 2006), extend the harvest season and avoid glut. While flowering and harvesting time may change every year depending on the environmental conditions, especially temperature (Ruiz and Egea 2008), the fruit development period (number of days from full bloom to maturity) remains more or less stable for each accession (Mounzer *et al*. 2008). This helps to design plantations for early as well as late harvesting for different purposes. But spring temperature influences the harvest date of peach cultivars (López and DeJong, 2007). Furthermore, the number of flowers per plant is an expression of productiveness if successfully converted into fruits. Drastic variability in number of flowers per plant was recorded, which ranged from 54.77 in IC380693 to 848.25 in IC247430. Like wise rich variability was found in flower diameter also, which ranged from 2.08 cm in IC360698 to 4.25 cm in IC360689, respectively.

Variability in size of fruits is a criterion adopted by consumers as different groups of consumers need fruit for different purposes. In the collected germplasm, length of fruit was found to vary from 3.38 cm in IC247433 to 7.02 cm in IC247432, while variability in fruit width was found to range from 3.46 cm in IC247433 to 6.04 cm in IC360695. In the same way, considerable variability was found in fruit weight also which ranged 29.30g in IC247433 to 360.00g in IC247432 which is one of the main quantitative inherited trait determining yield and consumer acceptability. Rich variability was found in fruit volume which ranged from 13.95 cc in IC380693 to 200.00 cc in IC247431. Stone, which is hard endocarp, varied in length from 2.15 cm in IC247433 to 4.44 cm in IC247432 and in width from 1.27 cm in IC320193 to 2.73 cm in IC247430. Weight of stone ranged from

Table 3 : Values of stomatal size and frequency in seventeen peach accessions of Central Himalayan Region

IC Number	Place of germ plasm collection	Altitude (m)		Stomatal size (µm)		Stomatal frequency (Stomata.mm^{-2})	
		At native place	In field Gene bank	At native place	In field Gene bank	At native place	In field Gene bank
IC247432	Hartola	1610	1480	94±3.03*	97±2.96*	184±5.93	179±4.66
IC247430	Naikhana	1630	1480	111±3.58*	118±3.34*	187±5.90	179±5.12
IC247431	Gaderuva	1638	1480	90±2.90	94±2.26	188±5.80	174±2.42
IC360695	Losgyani	1670	1480	98±3.16*	103±3.05*	194±5.61	179±5.32
IC360698	Bhatiuda	1690	1480	88±2.83	95±2.47*	198±5.83	180±5.41
IC360693	Jhutiua	1705	1480	86±2.77	93±2.51	219±7.06	211±6.68
IC360691	Talla Ramgarh	1720	1480	88±2.83	94±2.61	231±8.41	216±5.24
IC320193	Wargal	1732	1480	83±2.67	92±2.62	240±7.74	222±7.56
IC247433	Mustamano	1750	1480	83±2.66	92±2.58	241±7.77	225±7.44
IC360690	Niglat	1800	1480	80±2.58	88±2.49	252±8.12	234±7.89
IC360689	Malla Niglat	1900	1480	86±2.77	93±2.67	266±7.61	239±7.51
IC360685	Dugai Estate	1978	1480	81±2.61	90±2.57	293±9.45	254±9.36
IC320194	Gagar	2080	1480	87±2.80	96±2.71*	308±9.93	279±9.84
IC360684	Sargakhet	2110	1480	83±2.67	92±2.59	329±9.61	291±9.56
IC360680	Dhanachuli	2160	1480	79±2.54	88±2.47	364±8.51*	305±8.32
IC360683	Mustamano	2190	1480	74±2.38	85±2.31	375±8.29*	317±8.16*
IC360682	Satbunga	2220	1480	66±2.12	78±2.06	396±8.80*	351±8.76*

Values given in the table are mean ± SE; * Significant at $p \leq 0.05$

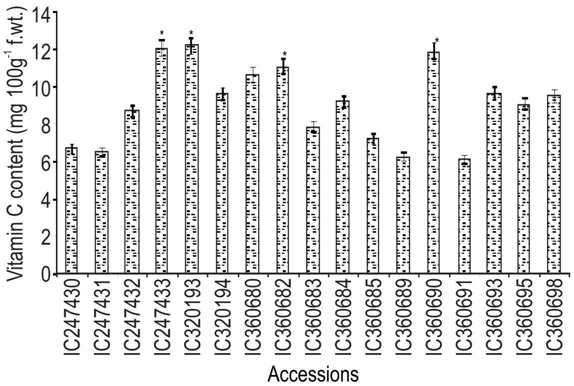

Fig. 2a : Genetic diversity in Vitamin C content of peach in Central Himalayan Region. *Significant at $p \leq 0.05$

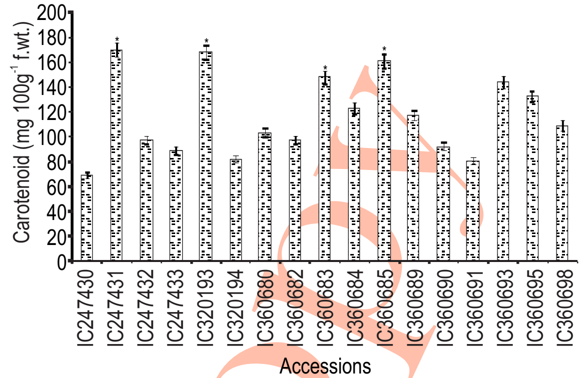

Fig. 2b : Genetic diversity in carotenoids content of peach in Central Himalayan Region. * Significant at $p \leq 0.05$

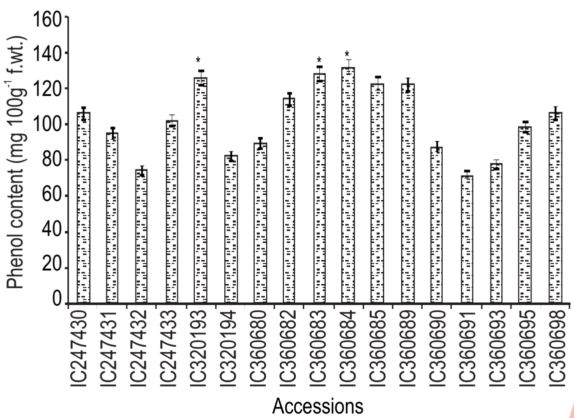

Fig. 2c : Genetic diversity in total phenols content of peach in Central Himalayan Region. * Significant at $p \leq 0.05$

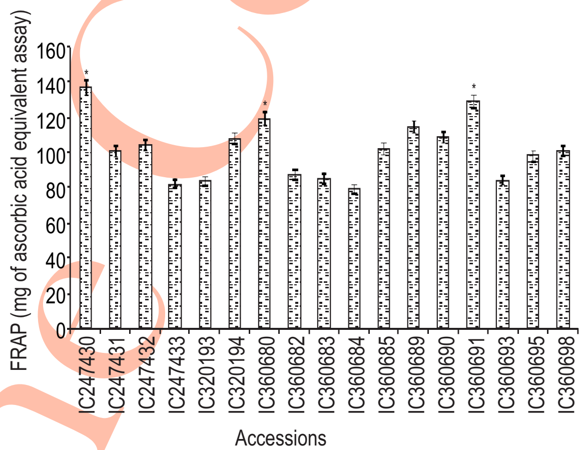

Fig. 2d : Genetic diversity in ferric reducing antioxidant potential (FRAP) of peach in Central Himalayan Region. * Significant at $p \leq 0.05$

11.33g in IC247433 to 71.25g in IC360683. Due to such variability in size, weight and stone of fruit; pulp stone ratio ranged from 38.00 in IC247433 to 142.50 in IC320194. Total soluble solids ranged from 8.50 °Brix in IC247431 to 12.33 °Brix in Ic380693 (Table 2). These characters related with plant growth and architecture, yield, blooming and harvesting times and fruit quality are of quantitative nature (Etienne *et al*., 2002) and need special attention to work out.

Temperature on the earth's surface vary, changing during seasons as well as during the day and night. Temperature variation above and below a limit acts as abiotic stress. It has a strong impact on the survival, growth, reproduction and distribution of plants. Different strategies adopted by plants to adjust to the changing environmental conditions include changes in above (plant architecture, leaf size and venation, stomatal size and frequency) and below ground (root size and proliferation) plant parts. Changes in above ground plant parts are obvious and comparatively easy to study. Hence, evaluation of above ground plant parts such as stomatal size and frequency may be crucial in selection of suitable accessions for cultivation in different elevations and variable climatic conditions. These accessions were collected from an altitudinal range of 1610 m asl to 2220 m asl. When stomatal size was measured the site of collection (at native place), it ranged from 66 µm in IC360682 to 111 µm in IC247430 while in the field gene bank (at one site) stomatal size varied from 78 µm in IC360682 to 118 µm in IC247430. Similarly, stomatal frequency of different accessions ranged from 184 stomata mm^{-2} in IC247432 to 396 stomata.mm^{-2} in IC360682 at native places and 174 stomata mm^{-2} in IC247431 to 351 stomata mm^{-2} in IC360682 in the field gene bank, respectively (Table 3). Stomata occupy central position in the pathway for transport of water vapour, CO_2 and O_2. Regulation of stomatal conductance (g_s) is the main mechanism by which plants control gas exchange and leaf temperature (Salleo *et al*., 2000). With change in environmental conditions plants regulate stomatal conductance

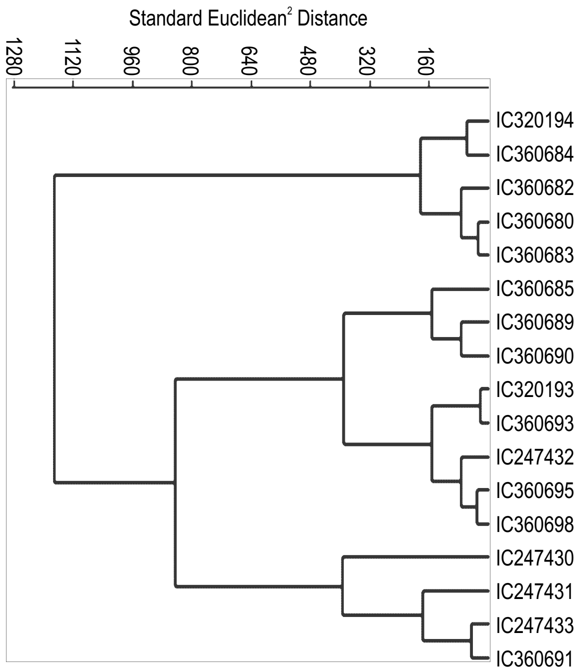

Fig. 3 : Ward's Minimum Variance Dendogram

through alteration in stomatal size and frequency (Trivedi *et al*., 2011). Alterations in stomatal size and frequency, if related to flowering and fruiting traits might have significant impact on selection of accessions for cultivation at different altitudinal ranges. Stomatal aperture is regulated by many stimuli which control the pressure potential of two guard cells that surround stomatal pore. When soil moisture decrease in fields, the stomata open for increasingly shorter periods during day. As a long term strategy in plant adaptation to changed environmental conditions changes in size and frequency of stomata take place. Chilling requirement is related to stomatal frequency and stomatal size. In general, chilling requirement has direct relationship with stomatal frequency and inverse relation with stomatal size. This relationship might be easily utilized for selection of accessions to be grown at different locations with variation in chilling hours.

Vitamin C content in fruit pulp of different accessions ranged from 6.12 mg.100g^{-1} f.wt. in IC360691 to 12.26 mg 100g^{-1} f.wt. in IC320193 (Fig. 2a). Moreover, variability in total carotenoid content ranged from 69 µg 100g^{-1} f.wt. in IC247430 to 170 µg 100g^{-1} f.wt. in IC247431 (Fig. 2b). Carotenoid content contributes to fruit colour; skin fruit colour has significant impact on consumer acceptance and sales of peaches (Liverani 2002). Similar variability was recorded in total phenol content also which ranged 72.1 mg.100g^{-1} f.wt. in IC360691 to 132.2 mg.100g^{-1} f.wt. in IC360684 (Fig. 2c). A positive correlation was noted between total phenolic compounds and antioxidant activity among red-flesh peaches and plums (Cevallos-Casals *et al*., 2005). Polyphenols deserve a special mention due to their free radical scavenging activities and *in vivo* biological activities. They play an important role in fruit color and taste. Moreover, ferric reducing antioxidant power of fruit pulp of different accessions ranged from 79.5 mg of ascorbic acid equivalent assay in IC360684 to 137.19 mg of ascorbic acid equivalent assay in IC247430 (Fig. 2d). The main health benefits of peaches are attributed to their antioxidant content. These compounds are effective against free radical species that can damage DNA, proteins and lipids. The fruit quality parameters are inter-dependent; therefore, relationship among them should be studied to improve the option of production objectives.

Cluster analysis was done to divide observations into homogeneous and distinct groups. Two main groups were formed (Fig. 3). Accessions collected from 1610 – 1978 m asl altitude were grouped in one group and accessions collected from 2080 m asl and above altitudinal range were grouped in another major group. Clustering partitions data set into groups such that the similarity within a group was larger than that among groups. In different sub groups accessions collected from similar altitudinal range were grouped together. Cluster analysis indicated that species naturally growing at similar elevations are closely related, these might have some common adaptations evolved through the process of evolution.

On the basis of vegetative characters, fruiting traits, antioxidant potential, stomatal behaviour and clustering of data it was concluded that germplasm collected from similar altitudinal ranges had common inherited traits. Based on morpho-physiological evaluation and stomatal study accessions, IC247432 and IC360682 were found suitable for cultivation at low and high altitude areas respectively. Inverse relationship of stomatal size and frequency found in the study might be crucial trait for selection of accessions to be grown at different locations varying in soil moisture and chilling hours.

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References

Benzie, I.E.F. and J.J. Strain: The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": The FRAP assay. *Anal. Biochem*., **239**, 70-76 (1996).

Cevallos-Casals, B., D. Byrne, W.R. Okie and L. Cisneros-Zevallos: Selecting new peach and plum genotypes rich in phenolic compounds and enhanced functional properties. *Food Chem.,* **96**, 273-280 (2005).

Chun, O.K., D. Kim, H.Y. Moon, H.G. Kang and C.Y. Lee: Contribution of individual polyphenolics to total oxidant capacity of plums. *J. Agr. Food Chem*., **51**, 7240-7245 (2003).

Etienne, C., C. Rothan, A. Moing, C. Plomion, C. Bodénes, L. Svanella-

Dumas, P. Cosson, V. Pronier, R. Monet and E. Dirlewanger: Candidate genes and QTLs for sugar organic acid content in peach *P. persica* (L.) Batsch. *Theor. App. Genet.,* **105**, 145 - 159 (2002).

Faust, M. and B.L. Timon: Origin and dissemination of peach. *Horticultural Reviews,* **17**, p. 331 (2010).

Liverani, A., D. Giovannini and F. Brandi: Increasing fruit quality of peaches and nectarines: the main goals of ISF-FO (Italy). *Acta Horticulturae,* **592**, 507-514 (2002).

López, G. and T.M. DeJong: Spring temperatures have a major effect on early stages of peach fruit growth. *J. Horticult. Sci. Biotechnol.,* **82**, 507-512 (2007).

Martínez-Calvo, J., G. Llácer, M. Cunill, S. Duran and M.L. Badenes: Programa de mejora de melocotonero del IVIA. *Actas de Horticult.,* **45**, 221-222 (2006).

Mounzer, O.H., W. Conejero, E. Nicolás, I. Abrisqueta, Y.V. García-Orellana, L.M. Tapia, J. Vera, J.M. Abrisqueta and M.C. Ruiz-Sánchez: Growth pattern and phenological stages of early-maturing peach trees under a Mediterranean climate. *Hort. Sci.,* **43**, 1813-1818 (2008).

Robinson, W.B. and E. Stotz: The indophenol xylene extraction method for ascorbic acid and modifications for interfering substances. *The J. Biol. Chem*., **160**, 217–225 (1945).

Ruiz, D. and J. Egea: Phenotypic diversity and relationships of fruit quality traits in apricot (*Prunus armeniaca* L.) germplasm. *Euphytica,* **163**, 143-158 (2008).

Salleo, S., A. Nardini, F. Pitt and M.A. Lo Gullo: Xylem cavitation and hydraulic control of stomatal conductance in laurel (*Laurus nobilis* L.). *Plant Cell Environ*., **23**, 71-79 (2000).

Schechter, I., J.T.A. Proctor and D.C. Elfving: Morphological difference among apple leaf types. *Hort. Sci*., **27**, 101–103 (1992).

Singh, A., R.K. Patel, K.D. Babu and L.C. De: "Low chiling peaches". Underutilized and underexploited horticultural crops. New Delhi: New India Publishing, p. 90 (2007).

Singleton, V.L. and J.A.Jr. Rossi: Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *Amer. J. Enol. Viticult.,* **16**, 144–158 (1965).

Soares-Cordeiro, A.S., S.P. Driscoll, M.C. Arrabac and C.H. Foyer: Dorsoventral variations in dark chilling effects on photosynthesis and stomatal function in *Paspalum dilatatum* leaves. *J. Exp. Bot*., **62**, 687–699 (2010).

Talcott, S.T. and L.R. Howard: Phenolic autoxidation is responsible for color degradation in processed carrot puree. *J. Agricult. Food Chem.,* **47**, 2109–2115 (1999).

Trivedi, A.K., R.R. Arya and K.S. Negi: Stomatal traits and flowering behavior as selection criteria in Apricots. *Intl. J. Fruit Sci*., **11,** 299–308 (2011).

Zhou, J.R., L. Yu, Z. Mai and G.L. Blackburn.: Combined inhibition of estrogen-dependent hurnan breast carcinoma by soy and tea bioactive components in mice. *Int. J. Cancer,* **108**, 8-14 (2004).