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Variations in the hybrid progeny of low chill white × yellow fleshed peaches

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ABSTRACT

Low chill Flordaglo (White flesh) × Florda Prince (Yellow flesh) hybrid population was studied for variations in flower and fruit traits. Useful variations in flower density, fruit density, fruit weight, fruit colour, fruit size and biochemical compounds was observed in the population. The hybrids showed variability for biochemical characters like total soluble solids (TSS), total sugars, reducing sugars, acidity, ascorbic acid, total phenols, antioxidant capacity, anthocyanin level and carotenoids. The range of biochemical characters in hybrids even exceeded that of the parents showing superiority of some hybrids to the parental varieties. Useful variation in fruit weight, fruit colour, fruit size and biochemical characters have been observed in the populations and the plants have been identified. Transgressive segregation has also been observed for fruit weight, size, TSS, carotenoids, phenols and extent of fruit colour. A significant positive correlation was found between flower density and fruit density (r = 0.9); fruit diameter and fruit length (r = 0.9); fruit weight and fruit diameter (r = 0.9); total sugars and TSS (r = 0.5); anthocyanin and total sugar content (r = 0.5); phenols and antioxidant activity (r = 0.4). The loci governing these traits seem to be combining in additive fashion in the population. The results from the chi-square test (χ2) for the goodness of fit showed that the segregation ratio for flesh colour in the Flordaglo × Florda Prince F_1population, fits in the BC_1F_1 population which is 1:1. Hence, the flesh colour seems to be governed by single gene.

Key words: *Prunus persica* (L.) Batsch, fruit quality, inheritance, antioxidants

INTRODUCTION

Peach is an important summer fruit grown worldwide over an area of 1.5 million hectares with an annual production of 25.8 million tonnes (FAOSTAT,12). The low chill (300 CU) peaches introduced by Punjab Agricultural University, Ludhiana during 1968 to 2001 served as an option to diversify to a crop with high economic returns due to precocious nature, high productivity, regular bearing and early maturity (April-May). Low chill peach varieties are being grown in the sub-tropical regions of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Uttar Pradesh and North and Eastern India (Rajput *et al*.,18). The restriction in the import of new peach varieties due to patent protection and commercial interests of private breeders in west has necessitated for breeding new indigenous peach varieties. Though, the low chilling requirement is the major characteristic for the economic cultivation of peaches in warmer subtropical regions but, attractive skin colour, texture, flesh colour, firmness, consistency and sugar/acid ratio are also very important breeding objectives. Fruit firmness, non-browning of the flesh and freedom from loose fibres are other major breeding targets. The fruit quality traits segregate in the hybrid populations due to heterozygous natures of the peach varieties. While, many single genes have been found that reduce the tree height, alter plant shape, and maintain flesh firmness, melting flesh, flesh colour, browning and freestone characters (Hancock *et al.,*13). The composition of sugars and organic acids during the ripening process play a pivotal role in flavour development of fruit. Anthocyanins and phenolics can be important targets for fruit breeding programmes. Metabolites have been characterized in peach varieties in different parts of the world (Mokrani *et al.,*16) and reported to have a large variations in the phytochemicals and metabolite contents in peach germplasm. It was hypothesized that crossing two diverse peach varieties (white and yellow flesh) can create some useful variation for fruit quality traits. Hence, the present study was undertaken to study the variability in physical and biochemical properties of low chill white × yellow fleshed hybrid peach population.

MATERIALS AND METHODS

This experiment was carried out at Fruit Research Farm, Department of Fruit Science, Punjab Agricultural University, Ludhiana. The Flordaglo (White flesh) × Florda Prince (Yellow flesh) hybrid

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population planted at 0.5×1.0 m during January, 2018 and trained to a central leader columnar system. The 86 F_1 hybrids were studiedduring the year 2020 and 2021.The hybrids which fruited in both the years were subjected to fruit quality analysis. The presence or absence of leaf glands on the leaf petiole was observed in mature leaves of peach hybrids. The shape of leaf gland was categorized as reniform and globose (round). The flowers of peach varieties and hybrids were classified as non-showy (campanulate) and showy (rosette) types by visual observations. The flower density, number of flower buds, number of nodes, number of fruits, blind node were recorded on randomly selected five shoots per tree. Flowering time was noticed with 5-10% open flowers, full bloom stage with 80% open flowers and flowering terminated, when all flowers opened. The fruit development period (FDP) was recorded from fruit set to harvest. Fruit length, diameter, depth and width of stalk cavity were measured in millimetres by using vernier calliper (Mitutoyo Corporation, Japan). The fruit weight was measured with electronic weighing balance. The flesh firmness was measured by penetrometer (Model FT-327, USA). The total soluble solids was recorded with the help of refractometer (Atago PAL 1 model 3810, Japan). The F_1 population was characterised for total sugars by Dubois method (Dubois *et al.,* 10), reducing sugarswith Nelson method (Nelson, 17), titratable acidity by titration with sodium hydroxide tophenolphthalein indicator, ascorbic acid with Folin- ciocalteau reagent method, total phenols by Swain and Hill (19) method and carotenoids by Barnes (2) . Anthocyanin content was determined by using ethanolic-hydrochloride extraction method and antioxidant capacity by DPPH scavenging method. The data for the year 2020 and 2021 were pooled except for the date of flowering and maturity. The principal component analysis was done with the statistical software XLSTAT (Addinsoft, USA). The segregation ratios of flesh colour in F_1 population of Flordaglo × Florda Prince were also assessed for Mendelian segregation of flesh colour using $\chi 2$ test.

RESULTS AND DISCUSSION

There was no variation among the parents, check variety and F_1 hybridsfor leaf glands, leaf gland shape and flower type. All the genotypes had reniform shaped leaf glands and showy flowers were found (Table 1). Ahuge variations for flower density (9.0 - 37 flowers/m), flowers per node (1-3), node density (28-50 nodes/m), fruit density (4.0-30.0 fruits/m) and blind node propensity (23.5- 43.2%) was recorded among the hybrids. Many hybrids had higher number of nodes and fruit density and

Table 1. Phenotypic and fruit characteristics of peach genotypes.

Genotypes	Presence of nectaries	Shape of nectaries	Flower type	Flower density (Flower/m)	Flowers per node	Node density (nodes/m)	Fruit density (fruits/m)	Fruit set (%)	Blind node propensity (%)	Fruit development period (Days)	Fruit length (mm)	Fruit diameter (mm)	Fruit weight (g)
Flordaglo	Present	Reniform	Showy	36.5 ± 0.6	2.3 ± 0.2	43.4 ± 0.5	21.3 ± 0.6	58.3 ± 2.1	33.4 ± 1.1	94.3 ± 0.6	50.6 ± 0.4	51.5 ± 0.4	80.1 ± 0.5
Florda Prince	Present	Reniform	Showy	38.5 ± 0.8	2.1 ± 0.2	42.5 ± 0.7	24.5 ± 0.9	64.7 ± 2.0	29.4 ± 1.2	80.6 ± 0.5	51.7 ± 0.3	53.1 ± 0.7	71.1 ± 3.3
Shan-i-Punjab (Check)	Present	Reniform	Showy	34.1 ± 0.3	2.3 ± 0.2	41.1 ± 0.4	25.5 ± 0.8	74.6 ± 2.1	29.6 ± 1.0	86.6 ± 0.9	63.8 ± 0.8	54.5 ± 0.8	86.6 ± 2.1
Flordaglo × Florda Prince	Present	Reniform	Showy	21.5 ± 0.7	1.4 ± 0.03	40.9 ± 0.3	14.7 ± 0.4	72.8 ± 0.7	35.9 ± 0.3	83.3 ± 0.4	51.1 ± 0.3	51.8 ± 1.2	68.1 ± 1.1
Range	-	-	-	9.0 - 37.0	1.0 - 3.0	28.0 - 50.0	4.0 - 30.0	40.0 - 90.0	23.5 - 43.2	74.0 - 102.0	32.1 - 55.8	34.8 - 62.9	32.0 - 113.0
CV	-	-	-	7.6	10.1	8.1	2.9	1.3	7.4	2.9	5.1	6.7	1.5

The values ± S.E.

lower blind node propensity over parents suggesting transgressive segregation. The flower and fruit density; and blind node formation depends upon several factors *viz*.,genotype, shoot length, number of nodes per meter and chilling hour availability. The blind node formation usually occur mostly under poor tree growth and high temperature (Boonprakob and Byrne,4). The fruit set (72.8%) ranged from 40.0 to 90.0% in the F_1 hybrids during both the years, which was higher than the parents. The fruit development period (FDP) varied from 74-102 days, while the FDP of 94.3 days and 80.6 days was recorded in the parents, Flordaglo and Florda Prince, respectively suggesting polygenic nature of inheritance of FDP (Vileila-Morales *et al*., 20). Some hybrids were very early maturing (FDP 74-78 days) over the parents. The highest fruit length (Table 1) was recorded in 'Shan-i-Punjab' (63.8mm). In the hybrids, the fruit length (51.1mm) and diameter (51.8mm) ranged from 32.1-55.8 mm and 34.8-62.9 mm, respectively. The average fruit weight (68.1g; range 32-113g) in the hybrids was quite less in comparison to the fruit weight in the parents (Flordaglo 80.1g and Florda Prince 71.1g) and the check (86.6g). However, the range of fruit weight (32-113g) showed that some of the hybrids in the population had higher fruit weight than the parents. The fruit weight and fruit size are quantitative traits,andinfluenced by many genes and environmental factors (Da Silva Linge*et al.*, 7).

The variation in the fruit colour (55-90%), flesh firmness (2.9 to 7.2 kg/cm^2), TSS (7.9-12.6°Brix), total sugars (7.5-11.7 %), reducing sugars (2.5 -5.8%) and acidity (0.46-0.89%) showed superiority of some of the hybrids over the parents (Table 2). This suggests a transgressive segregation for these characters in the hybrid population (Brooks *et al*.,5). The variation in flesh firmness might be related to genotype-specific differences in cell pore density, pectin and starch levels. In peach, soluble solid content is controlled by polygenes (Cantin*et al.,*6). The variation in FDP among the genotypes (Table 1) might have influenced the amount of starch broken down to simple sugars. In the peach hybrids, great variability was recorded for ascorbic acid (2.5-7.5mg/100g), phenolic content (11.3-119.9 mg/100g), antioxidant capacity (63.4-82.7 mg/100g), anthocyanin content (2.3-9.8 mg/100g), and carotenoids (3.3-123.4 mg/100g). The variability ofascorbic acid, phenolics, antioxidant capacity, anthocyanin content and carotenoids suggests the superiority of many hybrids over the parents. This variation in the hybrids might be due to genetic makeup and their response to environmental conditions which resulted in fruit over colour upto 90% (Table 1) and anthocyanin colouration in flesh (Fig. 3) of the hybrids.

A positive correlation (r =0.9) was recorded between flower density and fruit density; and fruit diameter and fruit length (Table 3) as reported by Milatovic *et al.* (15). The fruit weight was also positively correlated with fruit length (r = 0.8) and fruit diameter (r = 0.9). But, the fruit weight was negatively correlated with flower density, node density and fruit density, which reiterates the necessity of fruit thinning in peach. A significant positive correlation (r = 0.5) was recorded between total sugars and total soluble solids (TSS). A positive yet, non-significant correlation was observed between total sugars and fruit length, diameter, fruit weight and fruit over colour. Ayub*et al.*(1) also recorded positive correlation between sugars levels and total soluble solids (TSS) in peach. A highly significant and negative correlation (r = -0.5) was observed between phenols and the fruit development period suggesting a decrease in phenols with the fruit development (Liu *et al*., 14). A significant positive correlation (r = 0.4) was observed between anthocyanin and total sugar content which reiterates the role of sugars in the anthocyanin biosynthesis (Dai *et al.*,8). The phenol levels were also significantly correlated (r = 0.4) with the antioxidant capacity. Phenolic acids are the polyphenols, which are the main source of

Table 2. Biochemical characteristics of peach genotypes

Genotypes	Fruit colour (%)	Flesh firmness (Kg/ cm^2)	TSS (%)	Total sugars (%)	Reducing sugars (%)	Acidity (%)	Ascorbic acid (mg/100g)	Phenols (mg GAE/ 100g)	Antioxidants (mg/ 100g)	Anthocyanins (mg/ 100g)	Carotenoids (mg/ 100g)
Flordaglo	85.8 ± 1.5	3.5 ± 0.1	9.5 ± 0.1	8.6 ± 0.1	4.1 ± 0.1	0.79 ± 0.02	5.0 ± 0.1	38.2 ± 0.7	79.4 ± 0.7	3.5 ± 0.1	18.8 ± 0.5
Florda Prince	75.8 ± 1.5	5.5 ± 0.2	9.6 ± 0.1	8.8 ± 0.1	5.3 ± 0.1	0.65 ± 0.04	5.3 ± 0.1	39.8 ± 0.5	76.5 ± 0.8	3.6 ± 0.1	94.3 ± 0.6
Shan-i-Punjab (Check)	78.1 ± 1.7	7.2 ± 0.3	12.3 ± 0.1	8.3 ± 0.1	4.1 ± 0.1	0.76 ± 0.02	6.4 ± 0.2	32.7 ± 0.6	70.1 ± 0.6	4.9 ± 0.1	63.8 ± 0.5
Flordaglo × Florda Prince	75.3 ± 0.6	3.90 ± 0.2	9.8 ± 0.1	9.1 ± 0.1	4.2 ± 0.1	0.69 ± 0.01	4.1 ± 0.1	40.3 ± 1.6	74.8 ± 0.4	5.4 ± 0.1	51.6 ± 2.5
Range	55.0 - 90.0	2.8 - 7.2	7.9 - 12.6	7.5 - 11.7	2.5 - 5.8	0.46 - 0.89	2.5 - 7.5	11.3 - 119.9	63.4 - 82.7	2.3 - 9.8	3.3 - 123.4
CV	0.18	25.7	3.8	1.6	13.5	4.1	5.2	4.2	2.1	22.0	7.7

The values ± S.E.

Table 3. Pearson's correlation coefficients of peach genotypes for various parameters.

	Flr Density	ND	Fruit density	Fruit set	FDP	FL	FD	FW	FC	FF	TSS	TS	RS	TA	AA	Phenols	Antioxidants	Anthocyanins	Carotenoids
Flower density	1	0.3	0.9**	-0.2	-0.2	-.03	-0.2	-0.07	0.2	0.3	0.4*	0.3	0.2	0.1	0.2	0.05	0.2	0.2	0.1
ND		1	0.3	-01	0.1	0.03	0.04	-0.03	0.09	0.2	0.1	-0.2	-0.1	-0.12	0.2	-0.21	0.31	0.02	0.09
Fruit density			1	0.1	-0.2	-0.02	-0.2	-0.08	0.3	0.3	0.3	0.3	0.1	0.2	0.2	0.1	0.2	0.4*	-0.08
Fruit set				1	-0.01	0.07	0.002	0.2	-0.01	0.1	0.1	0.1	-0.1	-0.03	0.04	.006	0.07	0.2	-0.5**
FDP					1	-0.3	-0.1	-0.2	-.040	-0.1	-0.1	-0.1	-0.2	0.1	0.02	-0.5**	-0.004	-0.2	-0.2
FL					-0.3	1	0.9**	0.8**	0.3	-0.3	-0.1	0.1	0.3	.003	0.10	0.2	0.1	0.1	0.02
FD							1	0.9**	03	-0.2	0.01	0.1	0.3	-0.08	0.07	0.1	0.05	0.08	0.05
FW								1	0.2	-0.2	0.0	0.2	0.3	0.01	0.05	0.2	0.1	0.2	-0.1
FC									1	-0.1	0.1	0.3	0.2	-0.1	0.5**	0.03	0.1	0.1	-0.1
FF										1	0.5**	0.1	-0.05	0.007	0.05	0.1	0.2	-0.03	0.05
TSS											1	0.5**	0.2	0.3	0.1	0.2	0.2	0.08	-0.2
TS												1	0.5**	0.3	0.08	0.2	0.2	0.4*	-0.04
RS													1	0.4*	0.2	0.09	0.2	0.08	0.2
TA														1	-0.01	0.2	0.4*	0.1	-0.05
AA															1	-0.2	0.05	-0.1	-0.3
Phenols																1	0.4*	0.4*	0.1
Antioxidants																	1	0.4**	-0.1
Anthocyanins																		1	0.1
Cartenoids																			1

**. Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed).
Legend: ND: Node Density, FDP: Fruit Development Period, FL: Fruit Length, FD: Fruit Diameter, FW: Fruit weight, FC: Fruit Colour, FF: Flesh Firmness, TSS: Total soluble Solids, TS: Total Sugars, RS: Reducing Sugars, TA: Titratable Acid and AA: Ascorbic acids.

dietary antioxidants. The positive correlation between phenols and antioxidant capacity might be due to higher antioxidant activity of phenols in comparison to vitamins (Mokrani*et al.*,16).

In the hybrids, the full bloom stage (Table 4) was recorded from 13th February- 20th February (2020) and 11th February-18th February (2021). Some useful variationswere found in the progeny for flowering time as some F_1 hybrids were earlier in flowering than the check variety i.e. Shan-i-Punjab. This variation in the flowering time in peach hybrids might be related to genetic differences and their response to environmental conditions. The harvest time of the hybrids varied from 2nd May to 23rd May during the year 2020 and 29th April to 22nd May in 2021 (Table 4). In parental varieties, Florda Prince matured during last week of April and Flordaglo matured late i.e. last week of May. The wide range of useful maturity time was observed in the hybrids. This suggests that the trait is controlled by polygenes.

Principal component analysis of peach hybrids and varieties was done based on all yield contributing and fruit quality characters (Fig. 1). Among all the variables, fruit density (10.79%) contributed maximum followed by TSS (9.44%) while carotenoids (0.07%) contributed minimum in the first principal component. In PC2, fruit diameter (23.34%), fruit weight (20.19%) and fruit length (14.21%) contributed maximum in the total variability. In the third principal component, the major variables were phenols (20.51%), ascorbic acid (18.32%) and node density (9.93%). The dendrogram showed that the parents had high dissimilarity,falling in different clusters(Fig. 2). High harmony was found between Florda Prince, and its hybrids 3R/2. The hybrids were grouped in two main clusters. The cluster I had similarity with male parent 'Florda Prince' while, the female parent 'Flordaglo' was dissimilar with all the hybrids. The cluster II had two sub-clusters, the sub-cluster I had hybrids similar to Florda Prince while, sub-cluster II represented hybrids different from both the parents.The fruit skin pubescence was present in the parental genotypes. The majority of the hybrids (94.3%) had pubescent fruit skin, whileit was absent in 5.7% population (Fig.

Table 4. Flowering and harvesting time of peach genotypes

Genotypes	Flowering time		Harvest time	
	2020	2021	2020	2021
Flordaglo	15th February	13th February	28th May	25th May
Florda Prince	10th February	9th February	28th April	27th April
Shan-i-Punjab (Check)	17th February	15th February	7th May	5th May
Flordaglo × Florda Prince	13th February- 20th February	11th February-18th February	2nd May-23rd May	29th April- 22nd May

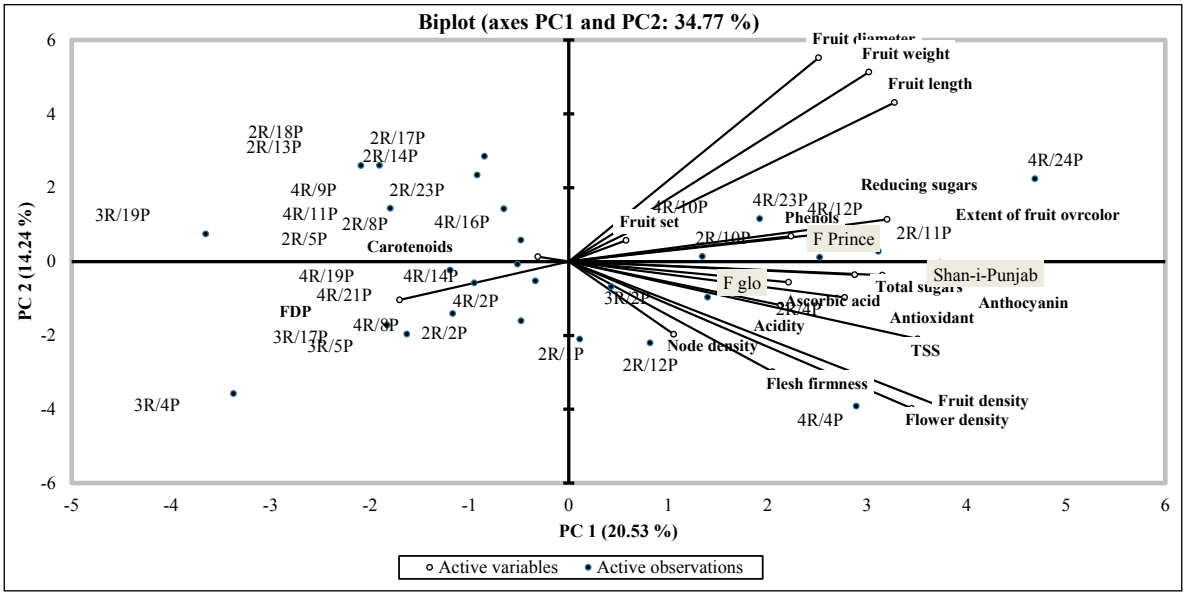

Fig. 1. Principal Components Analysis bi-plot scatter diagram showing the relative position of peach genotypes based on yield contributing and quality characters.

3A.). The absence of fruit skin pubescence as seen in nectarines is controlled by a single gene. Absence or presence of skin pubescence differentiate peach fromnectarines; the trait is recessive and controlled by G-locus (Dirlewanger *et al.,*9).

Among hybrid population, 91.5% of the individuals had round fruit, while remaining had ovate (5.7%) and oblate (2.8%).The fruit tip was absent in all the hybrids, and in Flordaglo, while it was present in Florda Prince and Shan-i-Punjab (Fig. 3B.). The absence of fruit tip is a very useful trait for better shelf life in peach. The variation in anthocyanin colouration of flesh was been noted in the hybrid progeny though, it was absent in the parents and the check variety. In the hybrid population, 51.28 % of the individuals lacked anthocyanin colouration in flesh, 5.12% of the individual had weak anthocyanin colouration around the stone, and 43.6% of the individuals had anthocyanin colouration only under the skin (Fig.3C). Presence or absence of anthocyanin is independent to skin ground colour, and can be quantitative and qualitative origin (Bassi and Monet, 3). Elliptical seeds were found in Flordaglo and check variety 'Shan-i-Punjab' while, Florda Prince had round shaped seeds. Among the hybrids, 66.7 % of the population had elliptical stones and 33.3 % had round shaped seeds (Fig.3D).The majority of the hybrids had large-sized stones (82.2%) and 15.3 % had medium and 2.5 % had small stone size.

The fruit skin over colour varied mottled (5.1%), marbled (41%), striped (33.4%) and solid flush (20.5%) in the hybrid population while, the parental genotypes had marbled pattern of skin over colour (Fig. 4A). The fruit ground colour is influenced by the genetic constitution of the varieties. In the cross combination involving green and yellow ground coloured varieties, the yellow and green ground colour segregated in 3:2 ratio in the F_1 population. Similar wide variation was observed in the fruit over colour segregation among population (Fig. 4B.). Among the F1 progeny, 51.6% of the individuals had dark red over colour, 34.2 % medium-blush and

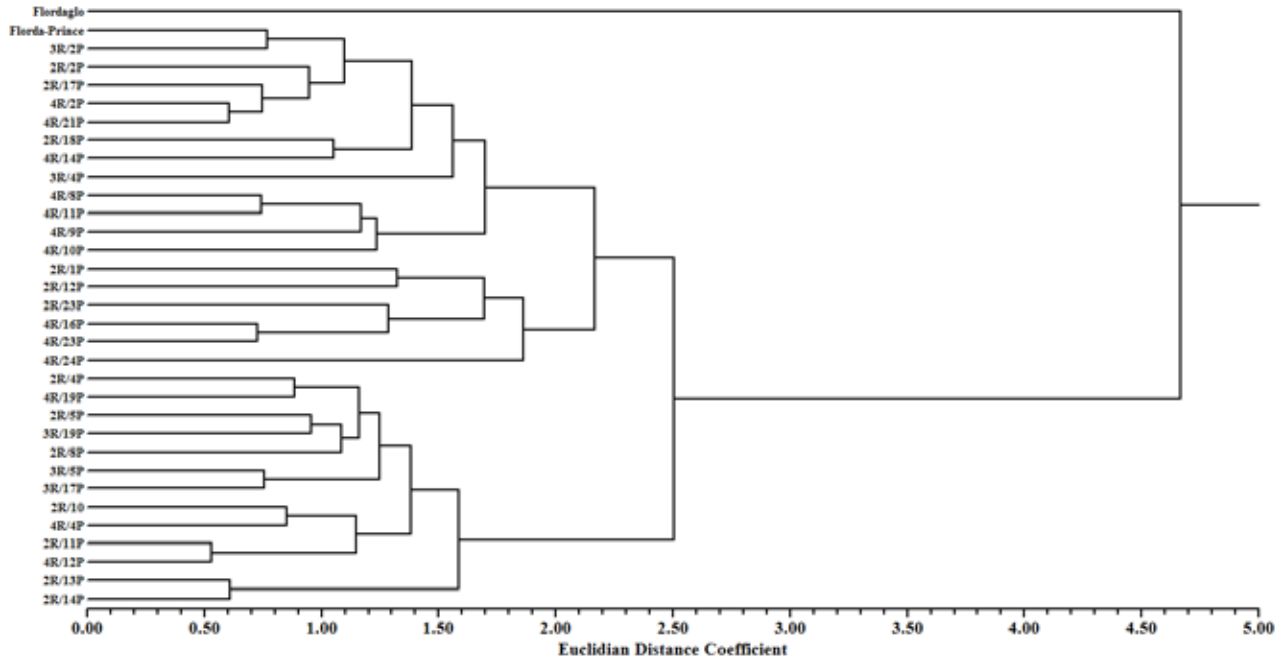

Fig. 2. Cluster dendrogram illustrating the genetic relationship between Flordaglo × Florda Prince hybrids and parents.

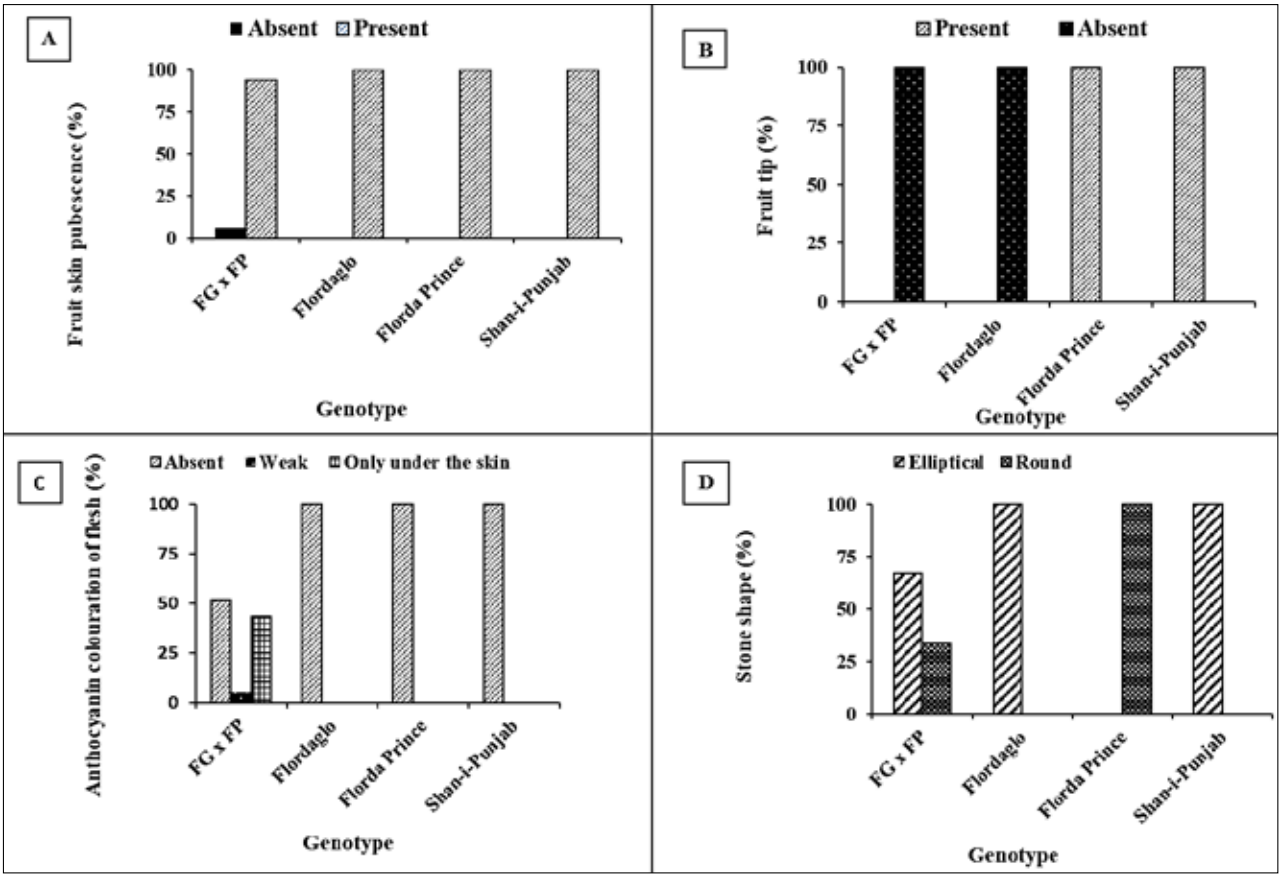

Fig. 3. Segregation of fruit (A) fruit skin pubescence, (B) fruit tip, (C) anthocyanin colouration in flesh and (D) stone shape in peach hybrid population.

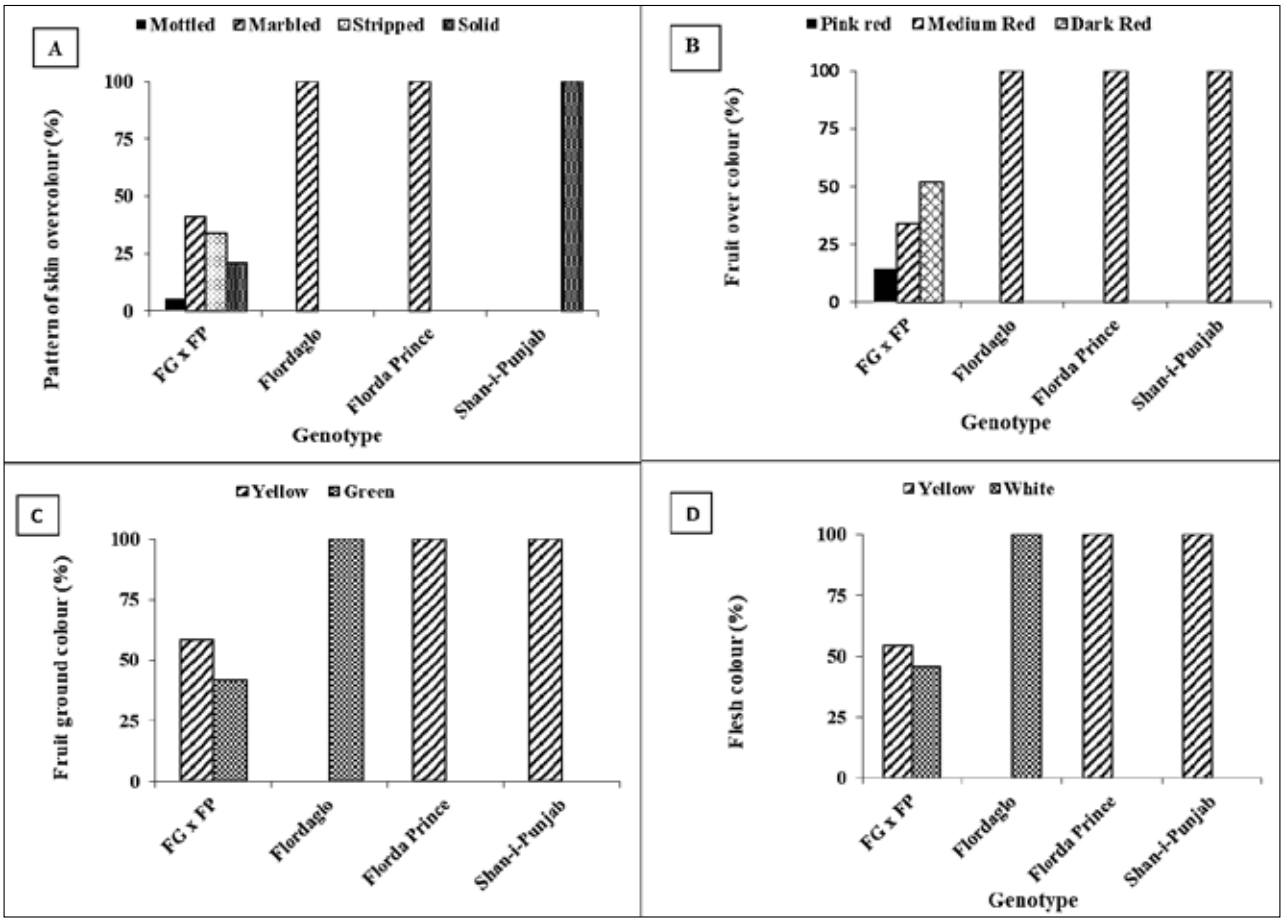

Fig. 4. Segregation of (A) pattern of skin over colour(B) fruit over colour, (C) fruit ground colour and (D) flesh colourin peach hybrid population.

remaining 14.2 % had pink-blush on the fruits. A wide range of extent of fruit colour (55%-90%) was observed in seedling population (Table 2) showing superiority of hybrids as compared to parents. Fruit over colour is a varietal trait and it differs because of the genetic constitution of different genotypes. In the hybrid population, 58.4% individuals had yellow ground colour while, the remaining 41.6 % individuals had green ground colour (Fig. 4C). The flesh colour of Flordaglo was white, while Florda Prince and check 'Shan-i-Punjab' it was be yellow. In case of the hybrids, 54.3 % of the progeny was found to be white-fleshed, while 45.7% of the population was yellow-fleshed (Fig. 4D). Peach flesh colour is controlled by a single gene mapping to linkage group 1 (Falchi *et al.*,11) with white flesh dominant over yellow flesh. The Chi-square test of goodness of fit was used to find the best fit for segregation ratio in F_1 population of Flordaglo × Florda Prince. The F_1 population fits in the BC_1F_1 which is 1:1. Hence, the flesh colour seems to be governed by a single gene.

AUTHORS' CONTRIBUTION

Conceptualization, design, methodology (AT, DB) Investigation (SS, AT, HS, DB); Statistical analyses (AT, DB) Manuscript writing (SS, AT, HS and DB).

DECLARATION

The authors declare no conflict of interest.

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