Variability and character association studies of yield and its contributing traits in low chilling peach, *Prunus persica* (L) Batsch genotypes

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ABSTRACT

Yield and yield contributing traits such as tree height, tree spread, trunk girth, tree volume, annual shoot growth, duration of flowering, flower density and fruit set were studied in ten low chill peach genotypes for two consecutive years 2013-2014 and 2014-15. Significant differences were found for all studied traits. The estimates of PCV were higher for all the traits investigated. High heritability coupled with high genetic gain was obtained for pulp to stone ratio. High heritability coupled with moderate genetic gain was obtained for yield per tree, fruit volume, fruit weight, sugar-acid ratio, non-reducing sugars and titratable acidity. A highly significant and positive phenotypic and genotypic correlations of yield were found with trunk girth, flower density, fruit set and fruit weight. Maximum positive direct effect cited towards yield were contributed by fruit set followed by average fruit volume, fruit weight, trunk girth, stone weight, tree volume and duration of flowering.

Keywords: Variability; heritability; correlation; path analysis; peach

INTRODUCTION

Peach, *Prunus persica* (L) Batsch is a widely cultivated and popular stone fruit in the temperate regions of the world. It belongs to family Rosaceae and is cultivated for table purposes as well as for processing. The commercial cultivation of peaches is primarily concentrated in temperate regions of the world across all the continents. It is widely cultivated in the regions extending from 10° North to 49° South latitude where strong light, clear skies, long seasons and warm temperature prevail mainly in low- and mid-hills with altitudinal range of 1000-2000 m amsl (Ghosh 2001). Most of the peach cultivars require 500-1000 chilling hours below 7.2°C to bloom normally in the spring. However some attempts in the past have led to the development of low chill cultivars of peach requiring100-300 hours of chilling which can successfully be grown in subtropical areas (Nijjar and Khajuria 1979). The low chill peaches developed in the past 20 years are promising for commercial production. A number of low chill peaches developed through breeding at different research stations all over the world particularly at the University of Florida have been tested and released for commercial production. However climatic fluctuations especially global warming leading to insufficient chilling affect the productivity of commercially grown peaches. Through judicious introduction a variation may be added to the fruit bowl of subtropical fruits and large unexploited areas in different parts of India can be subjected to cultivation of such peaches. Low chilling peaches are expanding at a faster pace as they come early in the market during the season and growers can get higher returns due to scarcity of other fresh fruits during this period.

The area and production of peaches in India during 2016-17 were18.00 thousand hectares and 107.00 thousand tonnes respectively (Anon 2017).

The assessment of variability is the first step of a breeding programme and the progress depends on the extent of genetic variability present in various biometric characters of the gene pool. It is the variation which if heritable could be used for crop improvement as varieties are the backbone of any orchard system. Therefore prior to recommendation of new cultivars they should be tested and extent of variability present must be adequately assessed so that they perform consistently over a long period of time. The present studies were therefore undertaken to estimate the genetic variability in respect of various quantitative and qualitative traits and evaluate interrelationships among yield and yield contributing traits in low chilling peach genotypes so as to bring improvement through future breeding programmes.

MATERIAL and METHODS

The present investigations were carried out at peach germplasm block of Department of Fruit Science, Nauni, Solan, Himachal Pradesh at 1275 m amsl for two consecutive years 2013-2014 and 2014-15. The experimental material consisted of eight year old ten low chilling peach genotypes viz TropicSweet, Saharanpur Prabhat, EarliGrande, Flordaprince, Tropicsnow, Flordaglo, ValleGrande, TropicBeauty, Pratap and FlordaGrande. Three uniform trees of each cultivar were taken for recording the observations. Data on fruit yield and its contributing traits were recorded in 2014 and 2015. The statistical analysis for each character was carried out on mean values from pooled data. The data were subjected to the analysis of various traits as described by Gomez and Gomez (1983). Coefficient of variability was calculated at phenotypic, genotypic and environmental levels by the formula suggested by Burton and Devane (1953). Heritability (%) in broad sense was calculated as per formula given by Burton and Devane (1953) and Johnson et al (1955). The expected genetic advance resulting from selection of five per cent superior individuals was also calculated by the formula suggested by Burton and Devane (1953) and Johnson et al (1955). Genetic gain expressed as genetic advance per cent of population mean was calculated by the method given by Johnson et al (1955). The genotypic and phenotypic correlation coefficients were calculated as per Al-Jibouri et al (1958) by implying the techniques of statistical analysis in variance-covariance matrix analysis in which total variability had been split into replications, genotypes and errors. The phenotypic and genotypic correlation coefficients were used in finding out their direct and indirect contribution towards yield per tree. Path analysis was done by the method given by Dewey and Lu (1959).

RESULTS and DISCUSSION

Variability studies

The estimates of average mean performance and genetic variability parameters for yield and component traits were worked out from analysis of variance and are presented in Table 1. The phenotypic coefficient of variation indicated higher values than genotypic coefficient of variation for all traits though with narrow differences for most of the characters. This indicates that these were less influenced by environmental factors. The estimates of phenotypic coefficients of variation were high (37.86%) for tree volume whereas moderate (15.00%) for tree spread, pulp to stone ratio (29.07%), non-reducing sugars (25.18%), fruit volume (23.74%), fruit weight (23.57%) and stone weight (21.04%) indicating the existence of substantial variability pointing ample scope for their improvement through selection. Greater improvement therefore could be obtained for these characters. Comparatively low phenotypic coefficient of variation was shown by the characters like tree height, tree spread, trunk girth, annual shoot growth, duration of flowering, flower density, fruit set, days from full bloom to harvest, fruit length, fruit breadth and fruit firmness. The low variation indicated the high stable nature of these characters among different genotypes studied and less scope of improvement in these characters.

The progress of breeding programme is conditioned by the magnitude and nature of genotypic and non-genotypic variations in the various characteristics. Since most of the economic characters like yield are complex in inheritance and are greatly influenced by the various environmental conditions the study of heritability and genetic gain is very useful in order to estimate the scope for improvement by selection. Heritability magnitude indicates the reliability with which the genotypes are recognized by its phenotypic expression. The heritability estimates were high for the characters like yield per tree (95.55%), tree height (89.38%), trunk girth (99.50%), duration of flowering (94.17%), flower density (95.48%), fruit set (99.68%), days from full bloom to maturity (99.98%), fruit length (99.92%), fruit breadth (99.51%), fruit weight (99.98%), fruit volume (99.94%), stone weight (97.78%), pulp to stone ratio (97.47%), total soluble solids (94.81), titratable acidity (97.84%) and total sugars (95.26%). High heritability estimates indicated that selection for these characters would be effective being less influenced by the environmental effects. Johnson et al (1955) impressed that heritability values

Table 1. Genetic variability analysis of yield and its contributing traits in low chilling peach genotypes

Trait	Mean	Range	Variance		Coefficient of variation (%)		Heritability (%)	Genetic advance	Genetic gain (%)
			Phenotypic	Genotypic	Phenotypic	Genotypic			
Tree height (m)	3.37	2.98-3.78	0.08	0.08	10.37	9.80	89.38	0.55	19.09
Tree spread (m)	2.89	2.29-3.60	0.09	0.04	15.00	9.75	42.50	0.26	13.05
Trunk girth (cm)	36.22	31.55-40.21	5.90	5.87	11.48	11.45	99.50	4.98	23.55
Tree volume (m^3)	15.42	8.71-25.81	5.64	2.72	37.86	26.30	48.25	2.36	37.63
Annual shoot growth (cm)	83.17	72.21-93.25	136.74	92.29	12.65	10.41	67.62	16.27	17.63
Duration of flowering (days)	31.50	27.50-36.50	9.72	9.16	9.84	9.55	94.17	6.05	19.08
Flower density	15.85	11.29-18.22	5.41	5.16	11.60	11.33	95.48	4.57	22.81
Fruit set (%)	61.64	51.10-71.00	47.89	47.74	11.32	11.31	99.68	14.21	23.25
# days from full bloom to maturity	116.00	93.50- 45.00	162.56	162.53	10.74	10.73	99.98	26.26	22.11
Fruit length (cm)	49.39	37.53-56.48	29.22	29.19	11.17	11.16	99.92	11.13	22.99
Fruit breadth (cm)	52.13	42.65-59.96	23.69	23.57	10.05	10.03	99.51	9.98	19.54
Fruit weight (g)	86.07	59.50-108.00	411.39	411.28	23.57	23.56	99.98	41.77	48.53
Fruit volume (cm^3)	83.77	57.46-105.75	406.17	405.91	23.74	23.73	99.94	41.49	48.89
Fruit firmness (kg/cm^2)	1.08	1.00-1.12	0.03	0.01	3.48	3.06	77.27	0.06	5.55
Stone weight (g)	4.81	3.87-7.19	2.71	2.65	21.04	20.81	97.78	3.32	42.40
Pulp to stone ratio	16.54	11.00-23.67	8.06	7.85	29.07	28.70	97.47	5.70	58.38
Yield/plant (kg)	6.90	5.98-8.09	0.58	0.55	11.41	11.15	95.55	1.49	22.46
Total soluble solids (^oB)	12.74	11.56-14.45	1.53	1.45	9.38	9.14	94.81	2.42	18.32
Titratable acidity (%)	0.78	0.66-0.88	0.03	0.02	20.66	20.43	97.84	0.27	41.64
Total sugars (%)	11.40	10.21-12.93	0.86	0.82	8.12	7.93	95.26	1.82	15.94
Reducing sugars (%)	8.69	7.68-9.98	0.35	0.24	6.83	5.68	69.24	0.85	9.74
Non-reducing sugars (%)	2.58	1.63-3.20	0.44	0.36	25.18	22.79	81.87	1.11	42.27
Sugar-acid ratio	18.72	14.67-25.84	15.63	15.04	21.69	21.27	96.19	7.83	42.97

along with estimation of genetic gain were more useful than heritability value alone in predicting the effect of selection. High heritability with high genetic gain was obtained for the character pulp to stone ratio whereas high heritability with moderate genetic gain was obtained for the characters fruit weight, fruit volume, stone weight, pulp to stone ratio, titratable acidity, non-reducing sugars and sugar-acid ratio which indicated that these characters were under the strong influence of additive gene action and hence simple selection based on phenotypic performance of these traits would be more effective. These results are in confirmation with the results obtained by earlier workers like Brooks et al (1993), De Souza et al (1998), Rakonjac and Zivanovic (2008), Milatovic et al (2010), Severa et al (2012) and Wu et al (2012). High heritability for sugars and acids observed was in accordance with Wu et al (2012). Milatovic et al (2010) observed relatively high value of heritability for flower density (83.00%) and yield (81.00%) whereas moderate heritability values were observed for initial (60.00%) and final fruit set (63.00%).

Association studies

Genotypic and phenotypic correlation coefficients are presented in Table 2. Correlation studies revealed that yield had positive association with trunk girth (0.48), flower density (0.54), fruit set (0.81) and fruit weight (0.50) indicating that selection of these traits would also lead to improvement in yield. The deviation in correlation coefficients may be due to heterogeneous population having differences in genetic makeup of individual genotypes. The significant and positive correlation between different pairs can be helpful for genetic improvement of different characters in a single step if the higher or lower values of each are required while the negatively associated traits where increased or decreased value of both the characters is required cannot be improved in a single step. The characters which had non-significant correlations suggested that they were independent of each other. Similar results were reported by De Souza et al (1998), Wu et al (2003), Rakonjac (2005), Drogoudi and Tsipouridis (2007), Rakonjac and Zivanovic (2008), Cantin et al (2010), Milatovic et al (2010) and Johnson et al (2011). In a study Saran (2007) reported that yield of peach genotypes had significant positive correlation with number of fruits set, fruit length, fruit diameter, fruit weight, stone weight and height of the tree. Similarly Font i Forcada et al (2014) reported that fruit yield in peach cultivars was positively correlated with trunk's cross-sectional area and fruit weight while it was negatively correlated with soluble solid content.

Since a correlation study measures the mutual association without regard to causation so correlation may not always provide a true picture of the association. The association becomes complex when many correlated characters are affecting a particular variable. In such situations a path coefficient analysis enables to evaluate the direct effect of one cause on an effect and its indirect effect through other causes. Here for path analysis fruit yield per plant was taken as dependent character and other component traits were considered as independent variables.

The direct and indirect effects of various traits were worked out from pooled correlation matrix and are presented in Table 3. Path analysis revealed that maximum positive direct effect towards yield per tree was contributed by fruit set (0.66), fruit volume (0.55), fruit weight (0.54), stone weight (0.27), flower density (0.23), tree volume (0.19), duration of flowering (0.11) and tree spread (0.06). Similar results were obtained by De Souza et al (1998) who observed that direct selection was practiced solely for early ripening and short fruit development period and was expected to have a greater effect on correlated traits than direct selection for early bloom and large fruit mass. Saran (2007) reported that fruit weight had highest direct and positive effect followed by number of flowers per shoot on yield per tree. Low magnitude of residual effect at genotypic level indicated that the traits included in the present investigations accounted for most of the variation present in the dependent variable that is fruit yield per plant. The studies on path coefficient analysis suggested that selection for fruit set (0.66), fruit volume (0.55), fruit weight (0.54), stone weight (0.27), flower density (0.23), tree volume (0.19), duration of flowering (0.11) and tree spread (0.06) would be effective for improving yield in low chill peach genotypes. On the basis of mean performance the genotype TropicSweet has been found promising for yield, fruit set, flower density, total soluble solids and non-reducing sugars. Although it is late maturing genotype yet it can be exploited in future breeding programmes.

Table 2. Phenotypic and genotypic coefficients of correlation among different traits in low chill peach genotypes

Trait		X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19
X1	P	0.51*	-0.13	0.27	0.79*	-0.45	0.38*	-0.10	-0.29	-0.11	0.17	0.18	-0.27	0.28	0.01	0.39*	0.36*	-0.22	0.36*
	G	0.72*	-0.12	0.43*	0.81*	-0.53	0.47*	-0.13	-0.37	-0.13	0.24	0.24	-0.33	0.33	0.01	0.41*	0.38*	-0.34	0.41*
X2	P		-0.03	0.86*	0.57*	-0.49	0.07	-0.10	-0.37	-0.11	0.10	0.14	0.07	-0.10	0.20	0.18	0.08	-0.51	0.12
	G		-0.03	0.91*	0.85*	-0.58	0.06	-0.11	-0.40	-0.13	0.12	0.14	0.07	-0.10	0.21	0.19	0.09	-0.54	0.16
X3	P			-0.09	-0.02	-0.44	0.14	0.69*	-0.31	-0.39	-0.30	-0.24	0.21	-0.16	-0.20	0.12	0.37*	0.03	-0.23
	G			-0.09	0.01	-0.50	0.15	0.74*	-0.32	-0.41	-0.31	-0.25	0.26	-0.16	-0.21	0.12	0.39*	0.03	-0.24
X4	P				0.40*	-0.26	0.06	-0.19	-0.29	-0.22	0.01	0.04	0.16	-0.21	0.22	-0.15	-0.18	-0.51	-0.10
	G				0.60*	-0.39	0.06	-0.20	-0.32	-0.23	0.01	0.03	0.18	-0.25	0.23	-0.16	-0.24	-0.57	-0.20
X5	P					-0.48	0.33	0.01	-0.33	-0.15	0.15	0.16	-0.19	0.18	0.01	0.43*	0.38*	-0.32	0.58*
	G					-0.59	0.41*	0.02	-0.42	-0.19	0.18	0.21	-0.24	0.23	0.07	0.52*	0.41*	-0.42	0.60*
X6	P						0.08	-0.22	-0.01	-0.02	-0.28	-0.32	0.07	-0.42	-0.01	-0.41	-0.11	0.71*	0.11
	G						0.09	-0.23	-0.01	-0.02	-0.29	-0.34	0.09	-0.46	-0.01	-0.44	-0.12	0.74*	0.13
X7	P							0.43*	-0.37	-0.25	-0.05	-0.04	-0.25	-0.39	0.24	0.17	0.49*	0.28	0.19
	G							0.43*	-0.38	-0.26	-0.05	-0.04	-0.25	-0.40	0.25	0.19	0.50*	0.32	0.24
X8	P								-0.05	0.11	0.12	0.17	0.06	-0.42	0.39*	0.36*	0.45*	0.19	0.13
	G								-0.05	0.12	0.12	0.18	0.05	-0.44	0.40*	0.37*	0.48*	0.21	0.15
X9	P									0.80*	0.77*	0.76*	-0.03	0.38*	0.48*	-0.06	-0.53	-0.22	-0.20
	G									0.81*	0.77*	0.76*	-0.04	0.40*	0.49*	-0.07	-0.59	-0.24	-0.24
X10	P										0.85*	0.84*	-0.16	0.13	0.71*	0.30	-0.18	-0.14	0.18
	G										0.85*	0.84*	-0.16	0.14	0.72*	0.31	-0.20	-0.15	0.22
X11	P											0.99*	-0.02	0.26	0.76*	0.21	-0.22	-0.27	0.15
	G											0.99*	-0.03	0.27	0.77*	0.21	-0.24	-0.30	0.16
X12	P												-0.03	0.26	0.78*	0.24	-0.21	-0.31	0.13
	G												-0.03	0.26	0.78*	0.25	-0.23	-0.34	0.15
X13	P													-0.33	0.10	-0.71	-0.35	0.16	-0.17
	G													-0.34	0.09	-0.74	-0.40	0.19	-0.22
X14	P														-0.38	0.23	-0.17	-0.42	-0.02
	G														-0.39	0.25	-0.22	-0.48	-0.06
X15	P															0.10	-0.12	-0.09	0.13
	G															0.09	-0.13	-0.09	0.16
X16	P																0.68*	-0.16	0.51*
	G																0.69*	-0.18	0.55*
X17	P																	0.45*	0.53*
	G																	0.48*	0.54*
X18	P																		0.23
	G																		0.30

X1= Tree height, X2= Tree spread, X3= Trunk girth, X4= Annual shoot growth, X5= Tree volume, X6= Duration of flowering, X7= Flower density, X8= Fruit set, X9= Fruit length, X10= Fruit breadth, X11= Fruit weight, X12= Fruit volume, X13= Fruit firmness, X14= Number of days from full bloom to maturity, X15= Stone weight, X16= Pulp to stone ratio, X17= Total soluble solids, X18= Titratable acidity, X 19= Total sugar, X20= Yield
G= Genotypic correlation value, P= Phenotypic correlation value, * Significant at 0.05 level

Table 3. Estimates of direct and indirect effects of different traits on yield of low chill peach genotypes

Trait	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20
X1	**-0.02**	0.05	0.05	-0.04	0.20	-0.06	-0.40	-0.22	0.07	0.18	0.13	0.13	0.40	-0.11	0.01	-0.37	-0.05	0.01	-0.04	-0.10
X2	-0.01	**0.06**	0.01	-0.09	0.16	-0.06	-0.05	-0.18	0.07	0.18	0.06	0.07	-0.09	0.04	0.06	-0.13	-0.01	0.01	-0.02	0.08
X3	0.01	-0.01	**0.41**	0.01	0.01	-0.05	-0.12	0.22	0.06	0.57	0.01	-0.14	-0.31	0.05	-0.06	-0.09	-0.05	-0.01	0.02	0.53*
X4	-0.01	0.05	-0.04	**-0.10**	0.11	-0.04	-0.05	-0.34	0.06	0.32	0.01	0.02	-0.22	0.08	0.06	0.11	0.03	0.01	0.10	0.16
X5	-0.02	-0.05	-0.01	-0.06	**0.19**	-0.06	0.34	0.03	0.08	-0.26	0.10	0.11	0.30	-0.06	-0.02	-0.37	-0.05	-0.04	-0.04	0.11
X6	0.01	-0.03	0.21	0.04	-0.11	**0.11**	-0.07	-0.39	0.01	0.02	-0.16	-0.19	-0.11	0.16	-0.01	0.32	0.01	-0.02	-0.01	-0.21
X7	-0.01	0.01	-0.06	-0.01	0.08	0.01	**0.23**	0.71	0.07	-0.56	-0.03	-0.02	0.31	0.13	0.07	-0.26	-0.07	-0.01	-0.02	0.57*
X8	0.01	-0.01	-0.31	0.26	0.12	-0.03	-0.36	**0.66**	0.02	-0.16	0.07	0.09	-0.07	0.25	0.11	0.27	-0.06	-0.01	-0.01	0.84*
X9	0.01	-0.02	0.13	0.03	-0.08	-0.01	0.31	-0.08	**-0.18**	-0.12	0.42	-0.41	-0.01	-0.13	0.14	0.05	-0.07	0.01	0.02	0.01
X10	0.01	-0.01	0.17	0.02	-0.09	-0.01	0.21	0.19	-0.15	**-0.39**	-0.46	0.45	0.20	-0.05	0.19	-0.22	0.02	0.01	-0.02	0.07
X11	0.01	0.01	0.09	-0.02	0.01	0.01	-0.20	0.62	-0.09	-0.10	**0.54**	-0.69	-0.11	0.13	0.37	-0.07	0.02	0.01	-0.01	0.53*
X12	-0.01	0.01	0.11	-0.01	0.11	-0.04	0.03	0.28	-0.14	-0.17	-0.54	**0.55**	0.04	-0.09	0.21	-0.17	0.03	0.01	-0.01	0.20
X13	0.01	0.01	-0.12	-0.02	-0.11	0.01	0.21	-0.09	0.01	-0.53	-0.01	-0.02	**-0.22**	0.12	0.03	0.52	0.05	-0.01	0.02	-0.14
X14	-0.01	-0.01	0.07	0.03	0.04	-0.05	0.33	-0.74	-0.07	-0.19	0.15	0.14	0.42	**-0.34**	-0.11	-0.18	0.03	0.01	0.01	-0.47
X15	-0.01	0.01	0.13	0.01	0.03	-0.03	0.04	0.20	-0.14	0.19	0.29	-0.67	0.03	-0.09	**0.27**	-0.15	0.03	0.01	-0.01	0.14
X16	-0.01	0.02	-0.05	0.02	0.10	-0.05	-0.14	0.62	0.01	-0.42	0.12	0.13	0.87	-0.08	0.02	**-0.73**	-0.09	0.01	-0.04	0.29
X17	-0.01	0.01	-0.16	0.04	0.08	-0.01	-0.45	0.81	0.12	0.28	-0.13	-0.12	0.49	0.08	-0.04	-0.50	**-0.12**	-0.01	-0.04	0.28
X18	0.01	-0.03	-0.01	0.06	-0.08	0.08	-0.27	0.35	0.04	0.21	-0.16	-0.18	-0.23	0.16	-0.02	0.13	-0.06	**-0.02**	-0.04	-0.06
X19	-0.01	0.01	0.10	0.02	0.11	0.02	-0.20	-0.27	0.04	0.30	0.09	0.08	0.27	0.02	0.04	-0.45	-0.14	-0.01	**-0.07**	-0.05

X1= Tree height, X2= Tree spread, X3= Trunk girth, X4= Annual shoot growth, X5= Tree volume, X6= Duration of flowering, X7= Flower density, X8= Fruit set, X9= Fruit length, X10= Fruit breadth, X11= Fruit weight, X12= Fruit volume, X13= Fruit firmness, X14= Number of days from full bloom to maturity, X15= Stone weight, X16= Pulp to stone ratio, X17= Total soluble solids, X18= Titratable acidity, X 19= Total sugar, X20= Yield correlation
Residual effect= 0.0103, Underline figures are direct effects, *Significant at 0.05 level

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