Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(5): 2158-2162
Received: 12-07-2020
Accepted: 22-08-2020

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Correlation and path coefficient analysis studies in Sapota [*Manilkara achras* (Mill.) Fosberg] genotypes

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Abstract
Assessment of variability and understanding of traits relationship in sapota are vital pre-requisite for formulating an effective breeding programme. A study was conducted to analyze the correlation and path coefficient for fruit yield and its yield attributing traits using 14 genotypes of sapota at Fruit Research Station, Navsari Agricultural University, Navsari (Gujarat). Fruit yield per plant showed highly significant and positive correlation with canopy spread East – West, number of leaves per shoot, number of flowers per shoot, L : B ratio, average fruit weight, number of fruits per tree, total soluble solids and chlorophyll content at both genotypic and phenotypic levels. Path coefficient analysis revealed that average fruit weight and number of fruits per tree had the highest direct effect on seed yield. This suggests that the two attributes have a strong influence on fruit yield. Hence, average fruit weight and number of fruits per tree are the main determiners of seed yield per plant in the studied variety.

Keywords: Sapota, correlation coefficient, path coefficient analysis

Introduction

Sapota (*Manilkara zapota*), known as sapodilla or chiku, is one of the prominent fruit species belonging to the family Sapotaceae. It is a native of Mexico and Central America and is now widely cultivated in West Indies, India, Mexico and other tropical countries. It is grown on a commercial basis in India, the Philippines, Sri Lanka, Malaysia, Mexico, Venezuela, Guatemala, and some other Central American countries. It is evergreen, tropical fruit tree, spreading habit and lives longer up to 100 years. In India, It has become more popular fruit crop in Maharashtra, Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu, Kerala, Uttar Pradesh, West Bengal, Punjab, Haryana. It is mainly cultivated for its fruits in India while, in South East Mexico, Guatemala, British Honduras and other countries chickle is commercially produced. The area and production of sapota in India is 0.97 lakh ha and 11.75 lakh MT, respectively. Out of which Gujarat alone covers 0.30 lakh ha area with 3.26 lakh MT production (Anon., 2019) [2].

Most of the present day sapota cultivars are the result of seedling selection and its cultivation is based on a narrow genetic base. Therefore, attempts are necessary for improvement of sapota by utilizing and selecting the variability. Gene pools are the reservoirs of variation which is the basis of improvement and essential for successful breeding programme. However, collection, conservation, characterization and documentation of genetic resources in sapota have not received any attention till today. With increased emphasis on sapota due to wide adaptability, ability to stand stress, high and continuous production and free from major pest and diseases, characterization, evaluation and documentation of sapota germplasm has been receiving attention. Progress in crop production depends to a great extent on the ability of the breeders to select high yielding varieties. Very little effort is currently being made in a number of sapota breeding programmes to improve yield attributes such as fruit yield, number of fruit per plant, and fruit weight. These traits are particularly important in the breeding of sapota programmes. Variation is a necessary condition for selection programme aimed at improving some desirable traits. Collection of genotypes and assessment of genetic diversity is a basic step in any crop improvement programme. Yield being a complex character is a function of several component characters and their interaction with environment. Probing of structure of yield involves assessment of mutual relationship among various characters contributing to the yield. Correlation measures the mutual association between two variables while path coefficient analysis identifies the causes and measures the relative importance of the association. Correlation coefficient measures the mutual association between a pair of variables ndependent of other variables to be considered.

Therefore, when more than two variables are involved, the correlations *per se* do not give the complete picture of their interrelationships. To evaluate relationships, correlation analyses are used such that the values of two characters are analyzed on a paired basis, results of which may be either positive or negative. The result of correlation is of great value in the determination of the most effective procedures for selection of superior genotypes. When there is positive association of major yield characters, component breeding would be very effective but when these characters are negatively associated, it would be difficult to exercise simultaneous selection for them in developing a variety.

Multiple regression and path coefficient analyses are particularly useful for the study of cause-and-effect relationships because they simultaneously consider several variables in the data set to obtain the coefficients. The establishment of a positive or negative relationship does not lead to a direct cause-and-effect interpretation, but a path coefficient analysis measures the direct influence of one variable upon another and permits the separation of the correlation into components of direct and indirect effects.

So far, none of the works carried out on yield attributes of sapota has been directed at identifying the characters that have influence on its fruit yield. The aim of this work, therefore, is to investigate the inter-relationship of yield attributes of sapota with a view to identifying the traits that contribute significantly to its fruit yield. The present study was, therefore, undertaken to estimate the extent of correlation coefficient among the selected characters and direct and indirect effects of component characters on yield of sapota.

Materials and Methods

The present investigation was carried out at Fruit Research Station, Navsari Agricultural University, Gandevi during year 2014 – 2015 to study the variability among sapota genotypes. Total 14 sapota genotypes of around 20 – 25 year age were used during the study. Observations were recorded on growth parameters like plant height, shoot length, canopy spread and number of leaves per shoot; reproductive parameters like days to fruit set and number of flowers per shoot; yield parameters like fruit yield, fruit length, fruit diameter, average fruit weight, l : b ratio, average number of seeds per fruit, fruit retention at harvest and number of fruits per tree; quality parameters like total soluble solids and acidity; average leaf size and chlorophyll content. The data were subjected to statistical analysis for assessing correlation and path analysis.

Character Association by Correlation Study and Path Analysis: Correlation and path-coefficient analysis were estimated by the association of characters and cause effect relationship studied for yield and component characters.

Estimation of Correlation

Association of different characters under the study was analyzed by the working out genotypic and phenotypic degree of correlation and simple correlation coefficient for all the possible parts of character combination by the method of Hayes *et al.* (1955) [7] and Al-Jabouri *et al.* (1958) [1].

Estimation of Direct and Indirect Effect of Different Characters on Yield

In order to find a clear picture of the inter-relationship between fruit yield and other components, path analysis splits the correlation coefficient into the measure of the direct and indirect effect of each contributing characters towards yield at genotypic level was done following Dewey and Lu (1959) [6].

Calculation of Residual Effect

After calculating the direct and indirect effect of different characters, the residual effect was calculated using the formula suggested by Singh and Choudhury (1985) [15].

Results and Discussion

Correlation among different agronomic and morphological characters is an important aspect for better planning of selection programs and is also helpful in determining the components of complex trait like yield. But the correlation alone cannot prove the exact picture of the relative importance of direct and indirect influences of each of the component characters towards yield. So, the character association is further analyzed through path coefficient. The adequate knowledge of interrelationship among various traits and the practices of unilateral selection for agronomic traits frequently end up in retrograde or less than an optimum result in plant breeding (Bhatt, 1973) [3]. The relationship between yield and its components may be due to genetic linkage, pleiotrophy or developmental causes. The correlation and path analysis studies are important assets to the breeder; especially in case of fruit crop like sapota, mango, and citrus, where in quantity and quality both are important. The information on the nature and magnitude of variability and correlation in a population owing to genetic and non-genetic factor is one of the prerequisites in any hybridization programme for selecting parents with desirable characters. In present investigation, the correlation between yield and yield contributing characters was measured and discussed.

Correlation studies

In selection process for crop improvement, knowledge of association of various characters is the most important tool (Desai *et al*., 1994) [5]. The genotypic and phenotypic correlation coefficients were analyzed and presented in Table 1. It appears that in most of the cases the genotypic correlation values were higher than their corresponding phenotypic values. This suggests that there were strong inherent relationship between the traits. The results showed that fruit yield was found to be highly significant and positively correlated with canopy spread East – West, number of leaves per shoot, number of flowers per shoot, L : B ratio, average fruit weight, number of fruits per tree, total soluble solids and chlorophyll content at genotypic and phenotypic levels. Similar results were obtained by Saraswathy *et al.* (2010) [14] in sapota for canopy spread East – West; Raghava and Tiwari (2008) [12] in guava and Islam *et al.* (2010) [8] in ber for average fruit weight; Saraswathy *et al.* (2010) [14] in sapota, Majumder *et al.* (2012a) [10] in mango and Thimmappaiah *et al.* (1985) [16] and Lakade *et al.* (2011) [9] in guava for number of fruits per tree and Lakade *et al.* (2011) [9] in guava for total soluble solids. These results indicated that increase in fruit weight and number of fruits per tree lead to increase in yield. Fruit yield had significant and positive correlation for shoot length and fruit diameter at genotypic and phenotypic levels while it had significant and positive correlation with canopy spread North – South, fruit retention at harvest and fruit length at genotypic level only which is in accordance with the findings of Thimmappaiah *et al.* (1985) [16] in guava for canopy spread North – South and fruit length.

Number of leaves per shoot showed positive and highly significant correlation with number of flowers per shoot, fruit diameter, fruit length, average fruit weight and chlorophyll content at genotypic and phenotypic levels and with L : B ratio at genotypic level only. It also showed significant and positive correlation with number of fruits per tree, average number of seeds per fruit and total soluble solids at genotypic and phenotypic levels and fruit retention at harvest at genotypic level. It had negative and significant correlation with L: B ratio at phenotypic level.

Number of flowers per shoot had highly significant and positive correlation with fruit diameter and average fruit weight at genotypic and phenotypic levels and L: B ratio, number of fruits per tree and chlorophyll content at genotypic level only. Fruit diameter (cm) had highly significant and positive correlation with average fruit weight and average number of seeds per fruit at genotypic and phenotypic levels and L : B ratio and fruit retention at harvest at genotypic level only. Similar results have been reported by Thimmappaiah *et al.* (1985) [16], Bandopadhyay *et al.* (1992) [4] and Raghava and Tiwari (2008) [12] in guava for average fruit weight. It also showed significant and positive correlation with L:B ratio and fruit retention at harvest at phenotypic level.

Fruit length (cm) had highly significant and positive correlation with average number of seeds per fruit, total soluble solids and chlorophyll content at genotypic and phenotypic levels and fruit retention at harvest at genotypic level. This indicated that the seed number affects the shape of fruit. Average fruit weight (g) had positive and highly significant correlation with average number of seeds per fruit and acidity at genotypic and phenotypic levels.

Number of fruits per tree had highly significant and positive correlation with total soluble solids at genotypic and phenotypic levels and chlorophyll content at genotypic level only. It showed significant and positive correlation with chlorophyll content at phenotypic level.

Average leaf size (cm^2) had highly significant and negative correlation with plant height, number of leaves per shoot, number of flowers per shoot and fruit diameter at genotypic and phenotypic levels and L : B ratio at genotypic level only. It also showed negative and significant correlation with fruit yield, shoot length and average number of seeds per fruit at genotypic and phenotypic levels. It had negative and significant correlation with canopy spread East – West at genotypic level and L : B ratio at phenotypic level.

Table 1: Genotypic and phenotypic correlation of fruit yield with other character in fourteen genotypes of sapota

Character		PH	SL	CSNS	CSEW	NLS	NFS	DFS	FD	FL	LBR	AFW	NFT	ANSF	FRH	TSS	ACI	CC	ALS
FY	r_g r_p	0.26 0.24	0.36* 0.34*	0.62** 0.31*	0.69** 0.43**	0.68** 0.65**	0.73** 0.62**	0.27 0.23	0.39* 0.37*	0.31* 0.28	0.55** 0.45**	0.47** 0.44**	0.75** 0.77**	0.14 0.13	0.54** 0.31*	0.67** 0.59**	0.14 0.11	0.65** 0.49**	-0.35* -0.33*
PH	r_g r_p		0.41** 0.31*	0.26 0.15	0.60** 0.36*	0.12 0.11	0.35* 0.28	0.44** 0.34*	0.38* 0.26	-0.46** -0.35*	0.96** 0.58**	0.35* 0.27	-0.04 0.04	0.07 0.08	0.25 0.12	0.12 0.01	0.82** 0.54**	-0.52** -0.31*	-0.45** -0.39**
SL	r_g r_p			0.14 0.12	0.83** 0.47**	0.57** 0.54**	0.71** 0.61**	0.01 0.01	0.73** 0.71**	0.01 0.01	0.48** 0.40**	0.75** 0.72**	-0.14 -0.14	0.29 0.25	0.60** 0.38*	0.23 0.20	0.29 0.26	0.28 0.21	-0.35* -0.31*
CSNS	r_g r_p				1.05** 0.12	0.23 0.13	0.27 0.18	0.81** 0.50**	0.33* 0.19	-0.24 -0.18	0.26 0.04	0.44** 0.24	0.33* 0.14	-0.02 -0.05	-0.25 0.26	-0.07 0.01	-0.00 0.08	0.31* 0.06	-0.11 -0.07
CSEW	r_g r_p					1.00** 0.22	0.66** 0.40**	0.44** 0.19	0.50** 0.27	-0.26 -0.11	0.87** 0.53**	0.44** 0.24	0.39* 0.26	-0.21 -0.09	0.64** 0.30	0.75** 0.32*	0.18 -0.01	0.24 -0.00	-0.37* -0.22
NLS	r_g r_p						0.85** 0.79**	0.16 0.15	0.62** 0.60**	0.49** 0.47**	0.42** 0.31*	0.61** 0.61**	0.32* 0.30*	0.33* 0.32*	0.31* 0.19	0.36* 0.33*	0.00 -0.01	0.57** 0.46**	-0.51** -0.49**
NFS	r_g r_p							0.16 0.12	0.56** 0.49**	0.20 0.18	0.44** 0.35*	0.50** 0.47**	0.43** 0.34*	0.27 0.28	0.31* 0.30	0.37* 0.35*	0.13 0.02	0.51** 0.30*	-0.62** -0.59**
DFS	r_g r_p								0.06 0.05	-0.27 -0.25	0.33* 0.27	0.09 0.08	0.21 0.17	-0.27 -0.25	-0.24 -0.11	-0.10 -0.10	0.28 0.22	-0.19 -0.14	-0.03 -0.01
FD	r_g r_p									0.13 0.12	0.45** 0.36*	0.86** 0.84**	-0.19 -0.16	0.45** 0.41**	0.49** 0.32*	0.01 0.00	0.22 0.18	0.07 0.09	-0.61** -0.56**
FL	r_g r_p										-0.06 -0.02	0.19 0.19	0.21 0.19	0.49** 0.46**	0.40** 0.20	0.44** 0.41**	-0.15 -0.14	0.62** 0.42**	0.10 0.08
LBR	r_g r_p											0.40** 0.33*	0.25 0.23	0.01 -0.01	0.50** 0.29	0.59** 0.45**	0.50** 0.36*	-0.18 -0.16	-0.46** -0.37*
AFW	r_g r_p												-0.21 -0.20	0.51** 0.49**	0.47** 0.29	0.08 0.07	0.50** 0.39**	0.38* 0.28	-0.28 -0.28
NFT	r_g r_p													-0.22 -0.19	0.20 0.11	0.67** 0.57**	-0.27 -0.18	0.47** 0.36*	-0.17 -0.16
ANSF	r_g r_p														0.21 0.16	0.12 0.12	0.32* 0.26	0.11 0.09	-0.33* -0.33*
FRH	r_g r_p															0.53** 0.36*	0.33* 0.18	0.43** 0.23	-0.18 -0.10
TSS	r_g r_p																0.00 0.01	0.40** 0.30	-0.15 -0.14
ACI	r_g r_p																	-0.26 -0.02	0.00 0.00
CC	r_g r_p																		0.24 0.21

** - Significant at $p = 0.01$ * - Significant at $p = 0.05$

PH – Plant height	SL – Shoot length	CSNS – Canopy spread North–South	CSEW – Canopy spread East–West
NLS – Number of leaves per shoot	NFS – Number of flowers per shoot	DFS – Days to fruit set	FD – Fruit diameter
FL – Fruit length	LBR – L : B ratio	AFW – Average fruit weight	NFT – Number of fruits per tree
FY – Fruit yield	ANSF – Average number of seeds per fruit	FRH – Fruit retention at harvest	TSS – Total Soluble Solids
ACI – Acidity	CC – Chlorophyll content	ALS – Average leaf size	

Path co-effcicent analysis

Significant genetic correlation coefficient between two characters does not always indicate presence of linkage between them. In order to find a clear picture of the inter-relationship between fruit yield and other components path coefficient analysis has been performed where yield of sapota was considered as resultant variable and the rest characters as causal variable. Direct and indirect effects of different yield contributing characters toward yield of sapota for genotypic level has been presented in Table 2.

In the present study, path coefficient analysis revealed that characters like average fruit weight (g) had highest positive direct effect on fruit yield followed by number of fruits per tree. Positive direct effect on fruit yield was recorded for fruit length (cm), chlorophyll content, canopy spread North – South (m), canopy spread East - West (m), fruit retention at harvest (%), L : B ratio, acidity (%), plant height (m) and number of flowers per shoot. Similar results were recorded by Raghava and Tiwari (2008) [12] in guava and Islam *et al.* (2010) [8] in ber for fruit length (cm); Saraswathy *et al.* (2010) [14] in sapota, and Islam *et al.* (2010) [8] in ber for canopy spread North – South (m); Saraswathy *et al.* (2010) [14] in sapota for canopy spread East – West (m); Majumder *et al.* (2012) [10] in mango for plant height (m) and Saran *et al.* (2007) in ber for number of flowers per shoot.

Average leaf size (cm^2), fruit diameter (cm), shoot length (cm), total soluble solids (^{0}Brix), number of leaves per shoot, average number of seeds per fruit and days to fruit set, had negative direct effect on fruit yield. Similar results were recorded by Raghava and Tiwari (2008) [12] in guava for fruit diameter (cm); Saraswathy *et al.* (2010) [14] in sapota for total soluble solids (^{0}Brix) and Raghava and Tiwari (2008) [12] in guava for average number of seeds per fruit.

Therefore, indirect selection practiced on these characters will result in the improvement of respective characters and ultimately fruit yield. The study of path analysis indicated that the direct selection of average fruit weight (g) and number of fruits per tree could be used as selection criteria for improvement in sapota.

Table 2: Direct and indirect effect of seventeen causal variables on fruit yield in fourteen genotypes of Sapota

Character	Direct effect	PH	SL	CSNS	CSEW	NLS	NFS	DFS	FD	FL	LBR	AFW	NFT	ANSF	FRH	TSS	ACI	CC	ALS	Correlation coefficient (r_g)
PH	0.063	-	0.026	0.016	0.038	0.007	0.022	0.028	0.024	-0.029	0.060	0.022	-0.002	0.004	0.016	0.007	0.051	-0.033	-0.028	0.26
SL	-0.157	-0.065	-	-0.022	-0.131	-0.089	-0.111	-0.001	-0.115	-0.001	-0.076	-0.117	0.023	-0.045	-0.094	-0.036	-0.046	-0.045	0.055	0.36*
CSNS	0.152	0.040	0.021	-	0.161	0.036	0.041	0.124	0.050	-0.037	0.040	0.067	0.051	-0.002	-0.038	-0.010	-0.000	0.047	-0.017	0.62**
CSEW	0.144	0.087	0.120	0.152	-	0.056	0.095	0.063	0.072	-0.038	0.126	0.064	0.056	-0.031	0.093	0.108	0.027	0.034	-0.054	0.69**
NLS	-0.116	-0.014	-0.067	-0.028	-0.046	-	-0.099	-0.018	-0.072	-0.057	-0.049	-0.072	-0.037	-0.039	-0.036	-0.042	-0.000	-0.067	0.059	0.68**
NFS	0.062	0.021	0.044	0.016	0.041	0.053	-	0.010	0.035	0.012	0.027	0.031	0.027	0.017	0.019	0.023	0.008	0.031	-0.039	0.73**
DFS	-0.029	-0.013	-0.000	-0.024	-0.013	-0.004	-0.004	-	-0.001	0.008	-0.010	-0.002	-0.006	0.008	0.007	0.003	-0.008	0.005	0.001	0.27
FD	-0.378	-0.147	-0.278	-0.126	-0.191	-0.235	-0.215	-0.022	-	-0.050	-0.172	-0.326	0.074	-0.170	-0.187	-0.003	-0.085	-0.027	0.234	0.39*
FL	0.252	-0.117	0.002	-0.062	-0.067	0.124	0.051	-0.070	0.033	-	-0.015	0.049	0.054	0.124	0.102	0.113	-0.038	0.157	0.025	0.31*
LBR	0.101	0.097	0.049	0.027	0.089	0.042	0.045	0.034	0.046	-0.006	-	0.041	0.026	0.001	0.050	0.059	0.051	-0.018	-0.047	0.55**
AFW	0.573	0.205	0.430	0.252	0.256	0.354	0.289	0.050	0.494	0.111	0.234	-	-0.121	0.297	0.273	0.047	0.289	0.218	-0.165	0.47**
NFT	0.499	-0.020	-0.074	0.167	0.195	0.161	0.218	0.109	-0.098	0.108	0.128	-0.105	-	-0.111	0.104	0.334	-0.135	0.237	-0.085	0.75**
ANSF	-0.100	-0.007	-0.029	0.001	0.021	-0.034	-0.027	0.028	-0.045	-0.049	-0.001	-0.052	0.022	-	-0.021	-0.012	-0.032	-0.011	0.033	0.14
FRH	0.134	0.034	0.080	-0.034	0.087	0.042	0.041	-0.033	0.066	0.054	0.067	0.064	0.028	0.029	-	0.071	0.044	0.057	-0.024	0.54**
TSS	-0.151	-0.018	-0.035	0.010	-0.114	-0.055	-0.056	0.015	-0.001	-0.068	-0.089	-0.012	-0.101	-0.019	-0.081	-	-0.000	-0.061	0.023	0.67**
ACI	0.087	0.071	0.026	-0.0006	0.016	0.0005	0.011	0.024	0.019	-0.013	0.044	0.044	-0.023	0.028	0.029	0.0001	-	-0.023	0.0001	0.14
CC	0.248	-0.129	0.071	0.077	0.059	0.142	0.126	-0.048	0.018	0.154	-0.045	0.094	0.118	0.028	0.107	0.101	-0.066	-	0.061	0.65**
ALS	-0.390	0.178	0.138	0.044	0.148	0.199	0.245	0.014	0.242	-0.039	0.182	0.112	0.067	0.129	0.070	0.061	-0.0004	-0.096	-	-0.35*

Residual Effect = Genotypic – 0.221

PH – Plant height	SL – Shoot length	CSNS – Canopy spread North–South	CSEW – Canopy spread East–West
NLS – Number of leaves per shoot	NFS – Number of flowers per shoot	DFS – Days to fruit set	FD – Fruit diameter
FL – Fruit length	LBR – L : B ratio	AFW – Average fruit weight	NFT – Number of fruits per tree
FY – Fruit yield	ANSF – Average number of seeds per fruit	FRH – Fruit retention at harvest	TSS – Total Soluble Solids
ACI – Acidity	CC – Chlorophyll content	ALS – Average leaf size	

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