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Variability analysis and PCA studies for fruiting behaviour in high density guava

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ABSTRACT

The investigations on PCA and variability analysis were conducted to understand the relationship among productivity traits of guava trees under high-density planting. This study established the link between agronomic and yield-related traits for the direct and indirect effects of independent variables on the crop's managerial capacity. Three districts of Himachal Pradesh, *viz*., Sirmaur, Kangra and Bilaspur, were specifically chosen. The multistage probability proportional to the size sampling design was used. Primary data were gathered on the vegetative development indices, blooming, generative, and fruiting factors. Trees in the high-density system were placed 2 × 1.5 m apart. Based on yield performance, a sample size of 160 trees was determined to be the ideal number, with 110 plants being 3-year-old and 50 being 8-year-old. Vegetative growth, flowering, generative and fruit quality characteristics are significantly and positively linked with yield. Path analysis confirmed that growth and generative features were the main contributors that could be the good indicators of increased yield.

Key words: *Psidium guajava* L., High density planting, Relationship analysis, Variability, Yield.

INTRODUCTION

Guava (*Psidium guajava* L.), regarded as the Apple of the Tropics, is native to Tropical America and belongs to the family Myrtaceae. In India, its cultivation covers 286 thousand ha with a yearly average production of 4,345 thousand MT. Due to its delicious taste and flavour, fruits have attracted a lot of interest (Mitra and Bose, 10). The relationship between yield and quality that contributes to it is crucial for plant breeding programmes to achieve high yield potential. Path coefficient analysis is only the way the inter-relationship among variables, whereas correlation assesses the mutual association between two variables. The correlation coefficient assesses the mutual link between two variables, with no other factors to be taken into account. The variables of the data set used to derive the coefficients, path coefficient analyses, and multiple regressions are helpful for the analysis of cause-and-effect relationships. However, the development of a positive or negative association does not directly translate into an interpretation of cause and effect. None of the research projects on the guava's yield characteristics to date have focused on figuring out the factors that affect how much fruit the plant produces. To determine the features, the purpose of this work is to investigate how the yield and other qualities of guava interact. It has been successful in explaining the interactions between yield and a number of other parameters using the path coefficient analysis.

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MATERIALS AND METHODS

Three districts of Himachal Pradesh, namely Sirmaur, Kangra, and Bilaspur, were selected purposely using a probability proportional to the size of the multi-stage sampling scheme. The data obtained on agro-morphological characteristics was subjected to variability analysis to test the significant difference in the variance of the various parameters. For various morphological features, mean, standard error, coefficient of variation, and fiducial limits were assessed for statistical significance. F-statistic was used to test the homogeneity of variance between two groups of plants, divided on the basis of their age, *i.e.*, 3- and 8-year-old plantations and location-wise comparison of variance was made by using Bartlett test and also to test the hypothesis for the variances of two independent random variables with a normal distribution and unknown expectation (Table 2). Karl Pearson's statistics for the correlation coefficient and the significance of the same is tested by t-statistic with n-2 degree of freedom. The coefficient analysis allows for the separation of the correlation coefficient into two components. It analyses the direct and indirect impact of various morphological features on guava yield and was employed in line with the procedure described by Wright (13) and Dewey and Lu (2). Calculations were also made to determine how strongly these factors influenced the dependent variables.

RESULTS AND DISCUSSION

A representative sample size of 160 trees comprised of 110 plants (3-year-old) and 50 plants (8-year-old) was selected. Data, including standard errors (SE), coefficients of variation (CV), and fiducial limitations, were averaged. Neyman and Proportional allocation methods were compared to generate precision-based estimates. Trees produced 4.78 kg of fruits per tree with 95% confidence intervals between 4.51 and 5.06 kg. Plant height (cm), trunk girth (cm), shoot growth (cm), leaf area (LA, cm^2), leaves, flower buds, flowers, length of flowering shoot, primary, secondary and tertiary branches, Tree Canopy Volume (TCV, m^3), Trunk Cross-Sectional area (TCSA, m^2), Canopy Area (CA, m^2), fruits per shoot, length and breadth of fruits with 95% fiducial limits of 153.56-159.44 cm, 6.35-7.38 cm, 12.03-12.95 cm, 55.16-57.29 cm^2, 12.47-13.42, 7.09-7.84, 5.07-5.58, 5.14-5.51 cm, 2.08-2.21,4.21-4.46, 8.07-8.85, 0.84-0.99 m^3, 3.78-4.92 cm,1.07-1.20 m^2, 2.84-3.00. TCSA had the highest coefficient of variation (69%), followed by TCV (42.30%).

Trees of the 8-year-old age group had a mean yield of 12.50 kg, with 95% fiducial limits. Mean plant height (cm), trunk girth (cm), shoot growth (cm), LA (cm^2), leaves per shoot, flower buds per shoot, flowers per shoot, length of the flowering shoot (cm), primary, secondary, tertiary branches, TCV (m^3), TCSA (cm), CA (m^2), fruits per shoot, length (mm), breadth (mm) and weight (g) of fruits was found as 213.30 cm, 17.18 cm, 20.69 cm, 57.08 cm^2, 14.12, 8.40, 6.06, 6.44 cm, 2.20, 4.50, 9.04, 2.21 m^3, 24.21 cm, 1.96 m^2, 4.28, 58.97 mm, 57.77 mm 132.84 g and 0.59 g/cm^2 with 95 per cent Fiducial limits 209.32-217.28 cm, 16.33-18.04 cm, 19.47-21.91 cm, 55.09-59.07 cm^2, 13.28-14.96, 7.73-9.07, 5.55-6.57, 6.21-6.66 cm, 2.09-2.31, 4.31-4.69, 8.34-9.74, 2.04-2.38 m^3, 21.82-26.61 (cm), 1.85- 2.06 m^2, 3.94-4.62, 56.59-61.35 mm, 56.01-59.53 mm,127.22-138.47 g and 0.52–0.66 g/cm^2, respectively. Similarly, plant height had the lowest coefficient of variation (6.57%), followed by fruit breadth (10.11%). TCSA had the highest CV (34%), followed by flowers (29.99%). Variability analysis evaluated for growth and fruiting characteristics showed the importance of variance in third- and 8-year-old plantations (Table 1).

Bartlett's test for homogeneity showed significant differences in trunk girth, shoot growth, LA, secondary and tertiary branches, TCV, TCSA, CA, yield, fruits per shoot, length, breadth and weight of fruits and yield efficiency. Studies of correlation are critical to enhancing yield through selective plant breeding if there is a substantial connection among economic variables. The relationship between morphological characters showed a positive link between yield and morphological characteristics. These studies were also confirmed by Gupta and Kour (3) in guava. In the current study, flower buds had a positive and substantial relationship with shoot growth, flowers, and fruits per shoot. Positive correlations between plant height, shoot growth, leaves per shoot, the flowers per shoot, length of flowering shoot, TCV, CA, and fruits per shoot were also found. These findings demonstrated a significant relationship between height, trunk girth, shoot growth, flowers per shoot, length of flowering shoot, tertiary branches, fruits per shoot, and breadth and weight of fruits. Maiti (8) investigated morphological components in using path coefficient analysis. Trunk girth was positively and significantly correlated with plant height, shoot growth, leaves per shoot, flower buds, flowers, TCV, length, breadth and weight of fruits. Plant height also exhibited a positive and significant correlation with trunk girth, shoot growth, LA, leaves per shoot, flowers per shoot, length, breadth and weight of fruits. Verma *et al*. (12) explored the interrelationship and

Table 1. Variability analysis of guava at different age groups in high density planting.

Trait	3-year-old	8-year-old	F-statistic
Plant height (cm)	242.20	196.46	1.23^{NS}
Trunk girth (cm)	7.56	9.01	1.19^{NS}
Shoot growth (cm)	5.93	18.47	3.12
Leaf area (cm^2)	31.63	49.26	1.56
Leaves per shoot	6.35	8.80	1.39^{NS}
Flower buds per shoot	3.96	5.51	1.39^{NS}
Flowers per shoot	1.84	3.28	1.79
Length of flowering shoot	0.92	0.64	1.45^{NS}
Primary branches	0.13	0.16	1.30^{NS}
Secondary branches	0.43	0.46	1.08^{NS}
Tertiary branches	4.27	6.00	1.40^{NS}
TCV (m^3)	0.15	0.35	2.35
TCSA (m^2)	9.01	70.93	7.88
CA (m^2)	0.12	0.14	1.18^{NS}
Fruits per shoot	0.76	1.47	1.93
Fruit yield (kg/tree)	2.13	5.44	2.56
Fruit length (mm)	38.45	70.03	1.82
Fruit breadth (mm)	31.15	38.28	1.23^{NS}
Fruit weight (g)	218.19	392.25	1.80
YE (g/cm^2 of TCSA)	1.59	0.06	25.78

Table 2. Variability analysis (location-wise) of guava trees.

Trait	Sirmaur			Bilaspur			Kangra			χ^2 0.05
	Variance	SE	CV	Variance	SE	CV	Variance	SE	CV	
Plant height (cm)	3.98	1.33	8.71	4.01	1.52	10.51	5.51	1.98	6.57	1.11 ^{NS}
Trunk girth (cm)	5.44	0.09	10.74	1.97	0.07	18.01	18.47	0.42	17.46	**113.41**
Shoot growth (cm)	1.80	0.22	16.89	1.91	0.13	12.87	3.28	0.61	20.77	**58.02**
Leaf area (cm^2)	0.48	0.54	10.14	0.93	0.53	9.93	0.64	0.99	12.30	**107.72**
Leaves per shoot	6.55	0.24	18.87	5.18	0.22	18.66	8.80	0.42	21.01	3.44 ^{NS}
Flower buds per shoot	32.41	0.19	26.73	31.30	0.19	26.84	49.26	0.33	27.95	1.80 ^{NS}
Flowers per shoot	0.98	0.13	25.39	0.53	0.13	25.71	9.01	0.26	29.90	5.87 ^{NS}
Length of flowering shoot	195.96	0.07	11.98	253.00	0.09	20.16	196.46	0.11	12.39	5.94 ^{NS}
Primary branches	0.17	0.03	16.07	0.04	0.04	17.14	0.14	0.06	18.37	1.44 ^{NS}
Secondary branches	2.29	0.04	10.61	0.22	0.08	18.93	70.93	0.10	15.06	**19.15**
Tertiary branches	0.21	0.22	26.55	0.05	0.15	19.16	0.35	0.35	27.09	**12.09**
TCV (m^3)	0.12	0.04	45.33	0.14	0.02	29.22	0.16	0.08	26.98	**37.40**
TCSA (m^2)	0.21	0.14	22.06	0.69	0.04	35.40	0.46	1.19	34.78	**445.57**
CA (m^2)	5.56	0.04	33.88	2.32	0.02	19.05	6.00	0.05	18.94	13.20
Fruits per shoot	40.94	0.09	31.30	18.84	0.08	26.27	38.28	0.17	28.34	**8.50**
Fruit yield (kg/tree)	0.84	0.07	12.12	0.66	0.09	26.06	1.47	0.33	18.66	**85.88**
Fruit length (mm)	39.81	0.60	12.10	36.69	0.58	11.34	70.03	1.18	14.19	**6.51**
Fruit breadth (mm)	167.42	0.61	12.20	266.47	0.41	8.06	392.25	0.87	10.71	**8.41**
Fruit weight (g)	0.51	1.23	11.81	0.81	1.56	14.18	5.44	2.80	14.91	**9.59**
YE (g/cm^2 of TCSA)	0.03	0.02	20.06	1.30	0.11	39.66	0.06	0.04	42.36	**195.44**

cause-effect analysis of Kinnow mandarin with yield contributing traits. These results were supported by Bharti *et al*. (1).

Dewey and Lu's (2) path coefficient analysis technique is beneficial for dividing the correlation coefficient into direct and indirect effects. The estimate of direct and indirect impacts was obtained in order to comprehend such effects of various independent characteristics or in conjunction with other characters on yield. Coefficients of correlation describe the strength of interactions among character pairings. Further, yield depends mutually on dependent component traits. Path analysis was used in the current study to calculate the direct and indirect effects of different growth features, fruit and yield-related attributes, and fruit yield per tree (Tables 3 & 4). The diagonal elements represent the direct effect. A residual of 0.18 indicates that 82% of the variation in the response variable was explained by independent variables. Trunk girth, fruit breadth, flowers per shoot, fruit weight, fruits per shoot, flowering shoot length, tertiary branches, CA, and TCV had the largest direct effects on yield. The highest indirect effect was caused by fruit breadth and trunk girth *via* plant height. Maximum positive indirect effects of shoot growth on yield were seen in trunk girth, fruit breadth and fruits per shoot.

Lal *et al*. (6) investigated genetic variability, correlation, and path-coefficient for panicle and yield of litchi. Trunk girth recorded the greatest influence on yield by significant indirect effect. Leaf number, TCV, CA, fruits per shoot, leaf area, flowers, tertiary branches, length, weight and breadth of fruits had positive indirect effects *via* trunk girth. The majority of parameters contributed are positive and indirectly to yield through trunk girth. Hamim *et al*. (4) reported similar results for okra genotypes. A residual value of 0.25 in the path model for 8-year-old trees was obtained, which means that the selected independent variables explain 75% of the variation in the response variable. TCSA, fruit breadth, flowers per shoot, fruit weight, LA, fruits per shoot, tertiary branches, leaf number, shoot growth, CA, TCV and plant height contributed positive and direct effects towards yield. Flowering shoot length and secondary branches directly affect yield negatively. Through TCSA, the majority of yield traits produced their most positive indirect contribution to

Table 3. Direct and indirect effects of morphological traits in 3-year-old guava plants.

Plant trait	Plant height	Trunk girth	Shoot growth	Leaf area	No. of leaves	No. of flower buds	No. of flowers	Length of flowering shoot	P	S	T	TCV	TCSA	CA	No. of fruits	Fruit length	Fruit breadth	Fruit weight	r*
Plant height	**-0.168**	0.871	-0.005	-0.001	-0.003	-0.008	-0.004	0.016	-0.005	-0.002	0.013	0.003	-0.575	0.005	0.012	-0.007	0.165	0.024	**0.332**
Trunk girth	-0.062	**2.347**	-0.012	-0.001	-0.014	-0.002	0.023	0.024	-0.006	0.000	0.011	0.006	-1.522	0.009	0.013	-0.029	0.046	0.009	**0.838**
Shoot growth	-0.045	1.629	**-0.018**	-0.001	-0.016	-0.022	0.047	0.023	-0.006	0.000	0.005	0.007	-1.106	0.011	0.021	-0.047	0.109	0.012	**0.605**
Leaf area	-0.027	0.557	-0.003	**-0.006**	0.000	0.002	0.003	0.006	-0.001	0.001	0.007	0.004	-0.338	0.009	0.005	-0.026	0.076	0.011	**0.279**
No. of leaves	-0.013	0.943	-0.008	0.000	**-0.034**	-0.010	0.026	0.016	-0.002	0.001	-0.001	0.002	-0.624	0.003	0.013	-0.039	0.033	0.007	**0.313**
No. of flower buds	-0.023	0.085	-0.007	0.000	-0.006	**-0.060**	0.062	0.002	0.002	0.002	-0.001	0.002	-0.081	0.003	0.028	0.004	0.049	0.011	0.072
No. of flowers	0.007	0.542	-0.008	0.000	-0.009	-0.038	**0.098**	0.001	-0.001	-0.001	-0.002	0.004	-0.365	0.008	0.024	-0.052	0.070	0.018	**0.296**
Length of flowering shoot	-0.056	1.173	-0.008	-0.001	-0.011	-0.003	0.002	**0.049**	-0.006	0.001	0.010	0.002	-0.758	0.001	0.005	-0.035	0.070	0.015	**0.448**
P	-0.016	0.281	-0.002	0.000	-0.002	0.002	0.002	0.006	**-0.049**	-0.008	0.006	0.001	-0.202	0.001	0.000	-0.004	0.008	0.003	0.028
S	-0.013	0.031	0.000	0.000	0.002	0.005	0.003	-0.001	-0.016	**-0.022**	0.012	-0.001	0.011	-0.001	-0.005	-0.021	0.042	0.009	0.035
T	-0.051	0.628	-0.002	-0.001	0.001	0.001	-0.004	0.011	-0.007	-0.006	**0.042**	0.005	-0.403	0.011	0.010	-0.009	0.070	0.014	**0.310**
TCV	-0.030	0.742	-0.007	-0.001	-0.004	-0.006	0.020	0.004	-0.002	0.001	0.012	**0.018**	-0.508	0.028	0.013	-0.022	0.060	0.002	**0.320**
TCSA	-0.063	2.327	-0.013	-0.001	-0.014	-0.003	0.023	0.024	-0.006	0.000	0.011	0.006	**-1.536**	0.009	0.013	-0.034	0.065	0.010	**0.818**
CA	-0.029	0.642	-0.006	-0.002	-0.004	-0.006	0.025	0.002	-0.001	0.001	0.015	0.016	-0.447	**0.031**	0.015	-0.046	0.106	0.011	**0.322**
No. of fruits	-0.042	0.594	-0.007	-0.001	-0.009	-0.034	0.048	0.004	0.000	0.002	0.008	0.005	-0.397	0.009	**0.049**	-0.007	0.075	0.012	**0.309**
Fruit length	-0.006	0.333	-0.004	-0.001	-0.007	0.001	0.025	0.008	-0.001	-0.002	0.002	0.002	-0.253	0.007	0.002	**-0.205**	0.371	0.040	**0.313**
Fruit breadth	-0.061	0.234	-0.004	-0.001	-0.002	-0.006	0.015	0.007	-0.001	-0.002	0.006	0.002	-0.217	0.007	0.008	-0.166	**0.457**	0.043	**0.320**
Fruit weight	-0.064	0.332	-0.003	-0.001	-0.004	-0.010	0.028	0.012	-0.002	-0.003	0.009	0.000	-0.251	0.006	0.009	-0.130	0.314	**0.063**	**0.303**

P-Primary branches, S- Secondary branches, T- Tertiary branches

Table 4. Direct and indirect effects of morphological characters of 8-year-old guava plants.

Plant trait	Plant height	Trunk girth	Shoot growth	Leaf area	No. of leaves	No. of flower buds	No. of flowers	Length of flowering shoot	P	S	T	TCV	TCSA	CA	No. of fruits	Fruit Length	Fruit breadth	Fruit weight	r*
Plant height	**0.014**	-0.675	0.037	0.048	0.037	-0.044	0.128	-0.004	0.001	-0.028	0.017	0.004	0.691	0.022	0.014	-0.350	0.343	0.134	**0.388**
Trunk girth	0.006	**-1.575**	0.033	0.031	0.052	-0.067	0.176	-0.007	0.001	-0.024	0.013	0.006	1.650	0.028	0.022	-0.401	0.281	0.137	**0.363**
Shoot growth	0.006	-0.654	**0.079**	0.049	0.062	-0.075	0.125	-0.021	0.002	-0.016	0.031	0.008	0.688	0.036	0.053	-0.176	0.143	0.068	**0.409**
Leaf area	0.004	-0.297	0.023	**0.166**	0.033	-0.017	0.059	-0.010	0.001	-0.021	0.039	0.003	0.312	0.021	0.013	-0.095	0.122	0.070	**0.425**
No. of leaves	0.004	-0.678	0.040	0.046	**0.121**	-0.059	0.114	-0.011	0.000	-0.018	0.024	0.006	0.719	0.027	0.026	-0.132	0.087	0.089	**0.405**
No. of flower buds	0.003	-0.457	0.026	0.012	0.031	**-0.230**	0.280	-0.025	0.000	-0.011	-0.003	0.005	0.488	0.013	0.111	0.111	-0.239	-0.004	0.111
No. of flowers	0.005	-0.768	0.027	0.027	0.038	-0.178	**0.361**	-0.018	0.001	-0.025	0.004	0.005	0.833	0.016	0.116	-0.026	-0.081	0.055	**0.391**

Contd...

Table 4 contd...

Plant trait	Plant height	Trunk girth	Shoot growth	Leaf area	No. of leaves	No. of flower buds	No. of flowers	Length of flowering shoot	P	S	T	TCV	TCSA	CA	No. of fruits	Fruit Length	Fruit breadth	Fruit weight	r*
Length of flowering shoot	0.001	-0.164	0.025	0.024	0.019	-0.082	0.096	**-0.069**	0.001	-0.013	0.032	0.001	0.169	0.007	0.044	0.144	-0.129	-0.016	0.089
P	0.003	-0.329	0.030	0.028	0.009	0.005	0.071	-0.008	**0.005**	-0.023	0.031	0.006	0.335	0.019	0.038	-0.074	-0.023	-0.018	0.107
S	0.004	-0.388	0.013	0.036	0.022	-0.027	0.092	-0.009	0.001	**-0.097**	0.046	0.001	0.434	0.020	0.016	-0.083	0.290	0.098	**0.471**
T	0.002	-0.155	0.018	0.047	0.021	0.005	0.010	-0.016	0.001	-0.033	**0.137**	0.000	0.161	0.007	0.010	-0.013	0.142	0.044	**0.387**
TCV	0.003	-0.507	0.034	0.023	0.037	-0.057	0.089	-0.002	0.002	-0.006	0.001	**0.019**	0.513	0.044	0.043	-0.087	-0.056	0.039	0.132
TCSA	0.006	-1.570	0.033	0.031	0.052	-0.068	0.182	-0.007	0.001	-0.026	0.013	0.006	**1.656**	0.028	0.023	-0.386	0.281	0.137	**0.393**
CA	0.005	-0.701	0.046	0.056	0.051	-0.048	0.092	-0.008	0.002	-0.032	0.015	0.014	0.751	**0.062**	0.010	-0.206	0.224	0.095	**0.429**
No. of fruits	0.001	-0.223	0.027	0.013	0.020	-0.164	0.267	-0.019	0.001	-0.010	0.008	0.005	0.244	0.004	**0.156**	0.147	-0.300	-0.030	0.148
Fruit length	0.007	-0.903	0.020	0.023	0.023	0.037	0.013	0.014	0.001	-0.012	0.002	0.002	0.915	0.018	-0.033	**-0.699**	0.647	0.169	**0.246**
Fruit breadth	0.006	-0.560	0.014	0.026	0.013	0.070	-0.037	0.011	0.000	-0.036	0.025	-0.001	0.589	0.018	-0.059	-0.573	**0.789**	0.185	**0.479**
Fruit weight	0.008	-0.923	0.023	0.049	0.046	0.004	0.085	0.005	0.000	-0.041	0.026	0.003	0.967	0.025	-0.020	-0.505	0.624	**0.234**	**0.610**

P-Primary branches, S- Secondary branches, T- Tertiary branches

guava yield. However, the highest positive indirect influence *via* fruit weight on yield was found. Flower buds, secondary branches and canopy area are all negative and were found to have the least indirect impact on yield. As a result, path analysis has been widely employed by researchers to fully assess how an independent variable affects a dependent one. Similar investigations were also documented by Lal (7) in fennel, Zhao *et al*. (14) in wheat, Majumder *et al*. (9) in potato, Udensi and Ikpeme (11) in *Cajanus cajan* and Kumar *et al.* (5) in mango.

The study found a significant and positive relationship between yield and agro-morphometric traits. Path analysis reveals that growth and generative traits were the main contributors to yield, which can be utilized through a breeding approach to increase yield, in high density planting of guava trees.

AUTHORS' CONTRIBUTION

Conceptualization of research (PKM, RK, AC, PK); Designing of the experiments (SB, PKM, RK, AC); Contribution of experimental materials (SB, PK); Analysis of data and interpretation (SB, PKM, RK, AC, PK); Preparation of the manuscript (SB, PK, SD); Review and editing (PK, SD).

DECLARATION

The authors declare that they do not have any conflict of interest.

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