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## Correlation and path analysis between yield and different morphological characters in Kinnow Mandarin (*C. Noballis* × *C. Deliciosa*)

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### Abstract

A study of interrelationship and cause-effect analysis of yield of Kinnow Mandarin (*C. Noballis* × *C. deliciosa*) and its component traits for 104 and 96 trees from Indora (Location L-1) and Indpur (Location L-2) blocks of Kangra district respectively had been done in 2014-15. F-test suggested that there was significant (1.47) variation among yield characteristics between these two locations except for fruit weight (gm) and LD ratio. Results obtained from path coefficient analysis, showed that for location L-1, number of fruits per branch (0.229), plant height (0.215) and tree girth (0.212) had highest and direct effect on yield per tree whereas for location L-2, fruit weight (0.38), number of flowers per branch (0.176) and plant girth (0.161) had highest direct effect on yield per plant. Thus, number of fruits per branch, number of flowers per branch and tree girth were the most important yield components of kinnow crop which should be exploited through a breeding programme for improving its yield potential.

**Keywords:** Correlation, Direct effect, Indirect effect, Kinnow Mandarin (*C. Noballis* × *C. deliciosa*), Path coefficient analysis, Variability analysis

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## INTRODUCTION

The adequate knowledge of association between yield and its contributing traits has a great importance in plant breeding. For any crop, to setup a suitable breeding programme, information about interrelationship among and between yield contributing characters is necessary. Correlation and the path coefficient analysis would provide a true picture of association among different traits (Bhatt, 1973). Path coefficient analysis, simply being a standardized partial regression coefficient, splits the correlation coefficient into the measures of direct and indirect effects (Dewey and Lu, 1959). Path analysis has widely been used by plant breeders to identify traits that are useful as selection criteria to improve yield (Milligan *et al.*, 1990; Surek and Beser, 2003).

Correlation coefficients between yield and yield components and direct and indirect effects of various plant characters on yield and yield components have been reported by Muhammad *et al.* (2002); Atta *et al.* (2008) and Padmavathi *et al.*

(2013). The present research was conducted to study inter-relationships among yield and its contributing traits of Kinnow Mandarin (*C. Noballis* × *C. Deliciosa*)

## MATERIALS AND METHODS

Field experiments were conducted during 2014-15 at farmers' orchards in Indora (L-1) and Indpur (L-2) blocks of Kangra district being the main kinnow growing belt of the Himachal Pradesh. A random sample of 104 and 96 trees from location L-1 and location L-2 respectively, was selected following a two-step approach as suggested by Stein (1945) and Cox (1958). According to this approach, in the first step, a small sample of size  $n_1$  is selected. Observations made on the units selected in this sample, are used to estimate various parameters involved in the expression for the half width of the confidence interval. After replacing the parameters by their respective estimates obtained from the preliminary sample, half width of the confidence interval are equated to the permissible error B. The equation is then solved for n, the required

sample size. If  $n > n_1$ , then  $(n-n_1)$  additional units are selected, which along with the preliminary sample yield a pooled sample of  $n$  units. If  $n < n_1$ , no more units are selected and preliminary sample is taken as the final sample. After selecting the samples, observations on yield per tree (Y), plant girth ( $X_2$ ), plant spread ( $X_3$ ), number of leaves per branch ( $X_4$ ), annual shoot extension growth ( $X_5$ ), number of flowers per branch ( $X_6$ ), number of fruits per branch ( $X_7$ ), fruit weight ( $X_8$ ), fruit set ( $X_9$ ) and Length x Diameter (LD) ratio ( $X_{10}$ ) were recorded. For calculating the Spread of the tree, average of East-West ( $X_{3E}$ ) and North-South ( $X_{3W}$ ) Spread was taken. From each of the selected trees, four branches were chosen randomly from each of four directions and observations on Number of leaves per branch, flowers and fruits per tertiary branch were recorded. Average values of these variables were taken for further analyses. The data so collected were subjected to correlation and path coefficient analysis.

**Estimation of correlation:** Yield is a complex character and is determined by many component characters. The identification of important characters and their interrelationship would be useful for developing improved trait. Thus, effective improvement in yield may be brought about through selection based on yield component characters. Correlation analysis for fruit yield provides opportunity for selection and leads to a directional model based on yield and its components in field experiments (Khan and Qureshi, 2001). Therefore, correlation study was carried out and correlation coefficient was estimated according to Prasad and Rao (1989).

**Estimation of path coefficient:** Path coefficient analysis is a technique of statistical analysis specially designed to quantify direct and indirect trait association with yield. When more characters are involved in correlation study it becomes difficult to ascertain the characters which significantly contribute to yield. The path coefficient analysis under such situations helps to determine the direct contribution of these characters and their indirect contributions via other characters. Hence, using correlation values, path coefficient analysis was carried out by following the procedure given by Dewey and Lu (1959) in which correlation co-efficient is partitioned into direct and indirect effects of independent variable(s) on the dependent variable. The estimated values were compared with table values of correlation coefficient to test the significance of correlation coefficient prescribed by Fisher and Yates (1967).

**Procedure for setting up the simultaneous equations:** The path coefficients were obtained by simultaneous selection of the following equations, which expresses the basic relationship between correlation 'r' and path coefficients (P).

$$r_{14} = P_{14} + P_{24}r_{12} + P_{34}r_{13}$$

$$r_{24} = P_{14}r_{21} + P_{24} + P_{34}r_{23}$$

$$r_{34} = P_{14}r_{31} + P_{24}r_{32} + P_{34}$$

where,  $r_{14}$ ,  $r_{24}$  and  $r_{34}$  are correlations of different morphological characters with yield (dependent character) and  $r_{12}$ ,  $r_{13}$  and  $r_{23}$  are the correlations among independent characters.

The direct effects and indirect effects were obtained by using the matrix methods.

The direct effect was obtained by following set of equations:

$$P_{14} = C_{11}r_{14} + C_{12}r_{24} + C_{13}r_{34}$$

$$P_{24} = C_{21}r_{14} + C_{22}r_{24} + C_{23}r_{34}$$

$$P_{34} = C_{31}r_{14} + C_{32}r_{24} + C_{33}r_{34}$$

where,  $C_{11}$ ,  $C_{22}$ ,  $C_{23}$  and  $C_{33}$  are constants and  $r_{12}$ ,  $r_{24}$ ,  $r_{13}$ ,  $r_{21}$ ,  $r_{14}$ ,  $r_{23}$ ,  $r_{34}$ ,  $r_{31}$ ,  $r_{14}$ ,  $r_{32}$ ,  $r_{24}$  are indirect effects.

**Residual effect:** The variation in the dependent variable which remained undetermined by including all the variables was assumed to be due to the variables not included in the present investigation. The degree of determination of such variable (s) on dependent variable was calculated as follows:

$$1 = P_1X_{42} + P_2X_{42} + P_3X_{42} + 2P_{14}r_{12}P_{24} + 2P_{14}r_{13}P_{34} + 2P_{24}r_{23}P_{34}$$

## RESULTS AND DISCUSSION

The data were collected on randomly selected trees from two locations viz. Indora (L-1) and Indpur (L-2) in 2014-15 for various tree growth characteristics viz. plant girth (cm), plant height (m), plant spread (m), number of leaves per branch, annual shoot extension growth (cm), number of flowers per branch, number of fruits per branch, fruit weight (gm) and yield per tree (kg) were subjected to various statistical measures viz. Mean, fiducial limit and coefficient of variation (Table 1). All the replicated data obtained from the experiments for consecutive two locations of study were statistically analysed using the F-test as per the procedure given by Gomez and Gomez (1984). For location L-1, mean fruit yield per plant was 24.63 kg with 95 per cent fiducial limit 22.68-26.58 whereas for location L-2, mean fruit yield was 25.27 kg with 95 per cent fiducial limit 23.50-26.84. F-test suggested that there was significant (1.47) variation among different morphological tree growth characteristics between these two locations except for fruit weight and LD ratio. This variation may be attributed to soil and fertility factors as well as hydro regime strata of the locality affecting microclimate at the growing stages.

**Correlation studies and path coefficient analysis:** Knowledge of correlation alone is often

**Table 1.** Mean and coefficient of variation of different growth characteristics.

Plant characteristics	Location L-1(n=104)				Location L-2 (n=96)				F-statistic
	Mean	SE	Fiducial limit	CV(%)	Mean	SE	Fiducial limit	CV(%)	
Plant height(m)	7.42	0.19	7.05-7.79	25.90	8.20	1.56	7.89-8.51	18.98	1.52*
Plant girth (cm)	23.43	0.48	22.48-24.38	21.06	26.81	3.68	26.07-27.55	13.73	1.80*
Plant spread (m)	4.71	0.11	4.49-4.93	24.83	4.56	0.99	4.36-4.76	21.64	1.41*
Number of leaves per branch	242.92	6.62	229.95-255.89	27.79	233.35	54.24	222.50-244.20	23.24	1.55*
Annual shoot extension growth (cm)	8.87	0.27	8.34-9.40	31.14	11.09	2.06	10.68-11.50	18.61	1.79*
Number of flowers per branch	52.31	1.51	49.35-55.27	29.48	56.34	12.90	53.76-58.92	22.90	1.43*
Number of fruits per branch	30.05	1.41	27.28-32.82	47.90	26.86	9.57	24.95-28.77	35.62	2.26*
Fruit weight(gm)	158.53	4.81	149.11-167.95	30.92	158.07	43.81	149.31-166.83	27.71	1.25
Fruit set (%)	54.62	1.39	51.89-57.35	26.01	47.17	11.02	44.97-49.37	23.35	1.66*
LD ratio	0.64	0.01	0.62-0.66	18.54	0.72	0.14	0.69-0.75	18.76	1.31
Yield per tree (Kg)	24.63	1.00	22.68-26.58	41.22	25.17	8.37	23.50-26.84	33.26	1.47*

**Table 2.** Correlation co-efficient between yield and yield contributing characters in location L-1.

Characters**	Plant height (m)	Plant girth (cm)	Plant spread (m)	Number of leaves per branch	Annual shoot extension growth (cm)	Number of flower per branch	Number of fruits per branch	Fruit weight (gm)	Fruit set (%)	LD ratio	Yield per plant (kg)
Plant height(m)	1	0.61*	0.58*	0.50*	0.31*	0.66*	0.67*	0.28*	0.54*	0.29*	0.76*
Plant girth (cm)		1	0.39*	0.45*	0.37*	0.64*	0.63*	0.34*	0.52*	0.36*	0.72*
Plant spread (m)			1	0.43*	0.41*	0.54*	0.61*	0.36*	0.56*	0.31*	0.67*
Number of leaves per branch				1	0.39*	0.58*	0.57*	0.30*	0.49*	0.30*	0.68*
Annual shoot extension growth(cm)					1	0.53*	0.49*	0.36*	0.36*	0.24*	0.53*
Number of flowers per branch						1	0.93*	0.46*	0.68*	0.40*	0.81*
Number of fruits per branch							1	0.43*	0.88*	0.42*	0.83*
Fruit weight(gm)								1	0.30*	0.25*	0.42*
Fruit set (%)									1	0.40*	0.72*
LD ratio										1	0.43*
Yield per tree (Kg)											1

\*Indicates significant at df=102 at 0.05 level of significance.

**Table 3.** Correlation co-efficient between yield and yield contributing characters in location L-2.

Characters**	Plant height (m)	Plant girth (cm)	Plant spread (m)	Number of leaves per branch	Annual shoot extension growth (cm)	Number of flower per branch	Number of fruits per branch	Fruit weight (gm)	Fruit set (%)	LD ratio	Yield per plant (kg)
Plant height(m)	1	0.58*	0.61*	0.42*	0.10	0.58*	0.63*	0.48*	0.38*	0.20	0.68*
Plant girth (cm)		1	0.29*	0.43*	0.25*	0.60*	0.59*	0.39*	0.23*	0.23*	0.65*
Plant spread (m)			1	0.32*	0.07	0.37*	0.38*	0.41*	0.22*	0.10	0.53*
Number of leaves per branch				1	0.26*	0.48*	0.48*	0.58*	0.22*	0.15	0.66*
Annual shoot extension growth (cm)					1	0.05	0.14	0.12	0.12	-0.05	0.18
Number of flowers per branch						1	0.80*	0.52*	0.17	0.35*	0.74*
Number of fruits per branch							1	0.51*	0.71*	0.38*	0.76*
Fruit weight(gm)								1	0.26*	0.03	0.77*
Fruit set (%)									1	0.21*	0.39*
LD ratio										1	0.30*
Yield per tree (Kg)											1

\*Indicates significant at df=94 and 0.05 level of significance.

**Table 4.** Path coefficient analysis of yield characters influencing kinnow yield in location L-1.

Characters	Plant height (m)	Plant girth (cm)	Plant spread (m)	Number of leaves per branch	Annual shoot extension growth (cm)	Number of flower per branch	Number of fruits per branch	Fruit weight (gm)	Fruit set (%)	LD ratio
Plant height(m)	0.215	0.131	0.125	0.106	0.066	0.141	0.143	0.059	0.116	0.062
Plant girth (cm)	0.129	0.212	0.082	0.095	0.078	0.136	0.134	0.072	0.110	0.076
Plant spread (m)	0.088	0.058	0.150	0.065	0.062	0.081	0.092	0.053	0.084	0.047
Number of leaves per branch	0.099	0.090	0.086	0.200	0.077	0.117	0.114	0.060	0.098	0.061
Annual shoot extension growth(cm)	0.028	0.034	0.037	0.035	0.091	0.048	0.045	0.033	0.033	0.022
Number of flowers per branch	0.021	0.020	0.017	0.018	0.017	0.032	0.029	0.014	0.022	0.013
Number of fruits per branch	0.153	0.144	0.140	0.131	0.113	0.214	0.229	0.099	0.201	0.095
Fruit weight(gm)	0.001	0.001	0.002	0.001	0.002	0.002	0.002	0.004	0.001	0.001
Fruit set (%)	0.017	0.017	0.018	0.016	0.012	0.022	0.028	0.010	0.032	0.013
LD ratio	0.013	0.015	0.014	0.013	0.010	0.017	0.018	0.011	0.017	0.043
Direct + indirect effect	0.764	0.723	0.671	0.681	0.528	0.809	0.835	0.416	0.716	0.433

Table 5. Path coefficient analysis of yield characters influencing kinnow yield in location L-2.

Characters	Plant height (m)	Plant girth (cm)	Plant spread (m)	Number of leaves per branch	Annual shoot extension growth (cm)	Number of flower per branch	Number of fruits per branch	Fruit weight (gm)	Fruit set (%)	LD ratio
Plant height(m)	0.090	0.052	0.054	0.038	0.009	0.052	0.056	0.043	0.034	0.018
Plant girth (cm)	0.093	0.161	0.046	0.069	0.041	0.096	0.095	0.063	0.038	0.037
Plant spread (m)	0.064	0.030	0.106	0.034	0.008	0.039	0.040	0.044	0.024	0.011
Number of leaves per branch	0.057	0.058	0.043	0.135	0.035	0.065	0.065	0.078	0.030	0.020
Annual shoot extension growth (cm)	0.002	0.005	0.001	0.005	0.021	0.001	0.003	0.002	0.002	-0.001
Number of flowers per branch	0.102	0.105	0.065	0.085	0.009	0.176	0.141	0.091	0.030	0.061
Number of fruits per branch	0.057	0.053	0.034	0.044	0.013	0.073	0.091	0.047	0.065	0.035
Fruit weight(gm)	0.182	0.149	0.157	0.220	0.044	0.198	0.196	0.382	0.101	0.013
Fruit set (%)	0.017	0.011	0.010	0.010	0.005	0.008	0.033	0.012	0.046	0.010
LD ratio	0.019	0.022	0.010	0.014	-0.005	0.033	0.036	0.003	0.020	0.094
Direct + indirect effect	0.684	0.647	0.527	0.655	0.179	0.748	0.751	0.742	0.355	0.297

misleading as the correlation observed may not be always true. Two characters may show correlation just because they are correlated with a common third one. In such cases, it becomes necessary to use a method which takes into account the casual relationship between the variables, in addition to the degree of such relationship. Path coefficient analysis measures the direct influence of one variable upon the other, and permits separation of correlation coefficients into components of direct and indirect effects. Portioning of total correlation into direct and indirect effects provide actual information on contribution of characters and thus form the basis for selection to improve the yield (Khan and Dar, 2010).

The Table 2 shows correlation coefficients for location L-1. It appears that yield had positive and significant correlation with number of fruits per branch (0.83) followed by the number of flowers per branch (0.81), plant height (0.76). This suggests that there was strong inherent relationship between the traits contributing towards the yield. It is evident that number of flowers per branch had highest and significant correlation (0.93) with number of fruits per branch. Majumder *et al.* (2012), also support the results of the present study. The results also showed that there were positive and significant correlation between number of fruits per branch with fruit set (0.88) followed by number of flowers per branch (0.68) and plant spread (0.56). From path coefficient analysis for location, L-1 (Table 4) indicated that the number of fruits per branch had maximum positive direct effect 0.229 on yield per plant. This implies that the selection of these traits (number of fruits per branch) would give better response in yield followed by plant height (0.215) and plant girth (0.212). While maximum positive indirect effect on yield was assessed by number of flowers per branch (0.214) via number of fruits per branch. The least indirect contribution to kinnow yield was via fruit weight followed by LD ratio. There was no direct and indirect negative effect of different traits towards yield. Results are in close agreement with Reddy *et al.* (2013) and Singh *et al.* (2013).

The correlation coefficients for location L-2 were calculated and presented in Table 3. It is evident that most of the characters were highly correlated with yield per tree. The results showed that fruit yield per tree had positive and significant correlation with fruit weight (0.77) followed by number of fruits per branch (0.76), flower per branch (0.74), plant height (0.68), annual shoot extension growth (0.66), plant girth (0.65) and plant spread (0.53). This indicates that the results of correlation studies between yield and yield contributing characters were significant for most of the characters under study and had strong inherent relationship among them. Therefore, selection for any of these traits would offer the scope for simultaneous

improvement of contributing characters in addition would be helpful in improving the yield potential in kinnow mandarin. Moreover, it is noticeable that yield was positively related with number of leaves per branch (0.18) although not significant. The perusal of path coefficient analysis (Table 5) for location L-2 showed that fruit weight had maximum positive direct effect (0.382) on yield followed by number of flowers per branch (0.176) and plant girth (0.161). The maximum positive indirect effect on yield was observed from annual shoot extension growth (0.22) via fruit weight. In contrast, indirect negative effect of number of leaves per branch (-0.005) through LD ratio and LD ratio (-0.001) via number of leaves per branch was observed. That means simultaneous selection for the characters might be effective in the improvement of fruit yield. Saha (2004) found maximum positive direct effect for average weight of flower on yield in lemon. Residual effects indicating the contribution of other factors on the variability other than the studied ones for location L-1 and location L-2 were calculated to be 0.37 and 0.39, respectively.

### Conclusion

Karl Pearson's correlation coefficient was worked out between kinnow yield and various morphological characters and results showed that yield per tree had positive and significant correlation with all morphological characters for location L-1, while for location L-2, fruit yield per tree had positive and significant correlation with fruit weight (0.77) followed by number of fruits per branch (0.76), number of flowers per branch (0.74). The use of simple correlation analysis cannot fully explain the relationships among different characters. Therefore, path coefficient analysis has been used by many researchers for a complete determination of the impact of different independent variables on dependent variable. It was observed that in location L-1, the number of fruits per branch had maximum positive direct effect (0.229) on yield per plant followed by plant height (0.215) and plant girth (0.212). In contrasts, it was also observed that maximum positive indirect effect on yield was assessed by number of flowers per plant (0.214) via number of fruits per branch. For location L-2, the result showed that fruits weight had maximum positive direct effect (0.382) on yield followed by number of flowers per branch (0.176), plant girth (0.161), whereas maximum positive indirect effect on yield was observed from annual shoot extension growth (0.22) via fruit weight, but LD ratio via number of leaves per branch were negatively correlated with kinnow yield. The path coefficient analysis helps the breeder to explain direct and indirect effects which have been extensively used in breeding works.

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