Plant Archives Vol. 26, No. 2, 2026 pp. 2615-2620 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.2.358

CHARACTER ASSOCIATION AND PATH COEFFICIENT ANALYSIS FOR FRUIT YIELD IN F_4 LINES OF BITTER GOURD (*Momordica charantia* L.)

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(Date of Receiving-17-08-2026; Date of Revision-16-10-2026; Date of Acceptance-21-10-2026)

ABSTRACT

Genotypic and phenotypic correlations and path coefficients were estimated for fruit yield per vine and eleven growths, flowering and fruit traits among twenty-two F_4 lines of bitter gourd derived from the crosses IC85633 × IC50526 and IC599421 × IC50526. The lines were evaluated in a randomised complete block design with two replications during *Kharif* 2026 at the College of Horticulture, Bagalkot. Genotypic correlations were generally higher than the corresponding phenotypic correlations. Fruit yield per vine was positively and significantly correlated with average fruit weight (rG = 0.762, rP = 0.740), vine length, number of fruits per vine, fruit length, fruit diameter and flesh thickness at both levels. It was negatively correlated with node to first female flower (rG = –0.721), days to first harvest and days to first female flowering. Average fruit weight and number of fruits per vine were almost uncorrelated with each other (rG = 0.098), so the two main yield components can be improved together. Path analysis showed that average fruit weight (0.504 genotypic, 0.503 phenotypic) and number of fruits per vine (0.508, 0.425) had the largest positive direct effects on yield. The positive associations of fruit length, fruit diameter and flesh thickness with yield arose mostly through indirect effects via fruit weight and fruit number. The earliness traits were strongly inter-correlated, and their genotypic direct effects were unstable in sign. The residual effects were 0.266 at the genotypic and 0.336 at the phenotypic level. Selection for heavier fruits, more fruits per vine and early flowering at a low node is suggested for improving fruit yield in these lines.

Key words : Bitter gourd, F_4 lines, Genotypic correlation, Phenotypic correlation, Path analysis, Direct effect, Fruit yield.

Introduction

Bitter gourd (*Momordica charantia* L., 2n = 2x = 22) is an important cucurbit vegetable in India, grown for its immature fruits, which are valued in the diet and in traditional medicine for their hypoglycaemic properties. Eastern India and southern China are regarded as the likely centres of its domestication (Behera *et al.*, 2023). The yield of the crop is still modest in many regions, and the development of high-yielding lines remains a major breeding objective.

Fruit yield is a complex trait that results from several component characters, many of which are themselves related to one another. Selection for yield alone is therefore inefficient and breeders usually rely on component traits that are strongly associated with yield and are easier to measure. Correlation coefficients show the strength and direction of these associations, but when many traits are inter-related, a correlation with yield may be largely due to the influence of another trait. Path coefficient analysis (Wright, 1921; Dewey and Lu, 1959) separates each correlation into a direct effect on yield

and indirect effects through other traits, and so helps to identify the characters that actually contribute to yield.

Most reports of character association in bitter gourd are based on germplasm collections. In advanced breeding lines such as the F_4, the associations reflect the gene combinations that have been retained after several generations of selfing and selection, and they are directly relevant to the choice of lines for further advancement. The present study was therefore undertaken to estimate genotypic and phenotypic correlations among yield and its component traits, and to partition these correlations into direct and indirect effects, in F_4 lines of bitter gourd derived from two intraspecific crosses.

Materials and Methods

The experiment was conducted during *Kharif* 2026 at the Experimental Block of the Department of Vegetable Science, College of Horticulture, Bagalkot (University of Horticultural Sciences, Bagalkot), Karnataka, located in the Northern Dry Zone (Zone 3) at 533 m above mean sea level. Twenty-two F_4 lines developed from the crosses IC85633 × IC50526 and IC599421 × IC50526, each obtained by selfing a single plant selected within an F_3 family were evaluated along with the check variety Phule Green Gold.

The trial was laid out in a randomised complete block design with two replications. Each line was grown in a 12 m² plot with ten plants per replication at 1.20 m × 1.00 m spacing. The crop was raised according to the package of practices of UHS, Bagalkot (Anonymous, 2013). Five plants per line in each replication were tagged at random and observations were recorded on vine length at last harvest (VL, m), number of branches per vine (NB), node to first female flower (NFF), days to first female flowering (DFF), days to first harvest (DFH), fruit length (FL, cm), fruit diameter (FD, mm), average fruit weight (AFW, g), number of fruits per vine (NFV), flesh thickness (FT, mm), cavity size (CS, mm) and fruit yield per vine (FYV, kg).

Genotypic and phenotypic correlation coefficients were computed from the variance and covariance components obtained from the analysis of variance and covariance, following Al-Jibouri *et al.* (1958) and their significance was tested with the t-test. Path coefficient analysis was carried out at both levels following Dewey and Lu (1959), with fruit yield per vine as the dependent variable and the other eleven traits as independent variables. Direct effects were obtained by solving the simultaneous equations relating the correlations of each trait with yield to the correlations among the traits and indirect effects were calculated as the product of the correlation between two traits and the direct effect of the second trait. The residual effect was estimated as $\sqrt{(1 - \Sigma \text{ Piy riy})}$. Direct and indirect effects were classed as negligible (below 0.10), low (0.10–0.19), moderate (0.20–0.29), high (0.30–0.99) and very high (1.00 and above) following Lenka and Misra (1973). The analyses were done in R (v4.3.1).

Results and Discussion

Correlation analysis : The genotypic and phenotypic correlation coefficients are presented in Tables 1 and 2, respectively. For most pairs of traits, the two coefficients had the same sign and the genotypic values were generally a little higher than the phenotypic ones. For instance, the correlation of fruit length with yield was 0.556 at the genotypic level and 0.337 at the phenotypic level. This indicates that the associations were largely genetic and were somewhat weakened at the phenotypic level by environmental effects. Number of fruits per vine was the only trait whose phenotypic correlation with yield (0.585) was slightly higher than its genotypic correlation (0.572).

Fruit yield per vine had its strongest positive association with average fruit weight (rG = 0.762, rP = 0.740), followed by vine length (0.714, 0.620), number of fruits per vine (0.572, 0.585), fruit length (0.556, 0.337), fruit diameter (0.512, 0.476) and flesh thickness (0.484, 0.450). All of these were significant at both levels. Lines with longer vines and heavier, longer and thicker-fleshed fruits, and with more fruits per vine, were thus generally the higher yielders. Positive associations of yield with fruit weight and fruit number in bitter gourd have been reported by Singh *et al.* (2012), Rani *et al.* (2015), Jatav *et al.* (2016), Moharana *et al.* (2018), Kishorkumar (2025) and Sahana (2025), with vine length by Sundaram (2010), with fruit length by Khan *et al.* (2015), and with fruit diameter by Islam *et al.* (2014). Number of branches was positively but not significantly related to yield (0.252, 0.231), so branching by itself was of little consequence for yield in these lines.

Node to first female flower (rG = –0.721, rP = –0.665), days to first harvest (–0.582, –0.528) and days to first female flowering (–0.504, –0.471) were negatively and significantly correlated with yield. These three earliness traits were also strongly correlated among themselves (rG = 0.700 to 0.896). Lines that produced their first female flower at a lower node flowered and fruited earlier and gave higher yields, presumably because early fruit set lengthens the harvesting period within a fixed crop duration. The earliness traits were also negatively associated with fruit length, fruit weight and

Table 1 : Genotypic correlation coefficients among growth, flowering, fruit and yield traits in F_4 lines of bitter gourd.

Traits	VL	NB	NFF	DFF	DFH	FL	FD	AFW	NFV	FT	CS	FYV
VL	**1.000**	0.035	–0.490*	–0.541**	–0.589**	0.224	0.198	0.556**	0.287	0.285	–0.363	0.714**
NB		**1.000**	–0.193	–0.003	–0.220	0.683**	0.206	0.001	0.230	0.273	–0.035	0.252
NFF			**1.000**	0.700**	0.774**	–0.651**	–0.461*	–0.596**	–0.398*	–0.610**	0.254	–0.721**
DFF				**1.000**	0.896**	–0.590**	–0.033	–0.320	–0.315	–0.363	0.424*	–0.504**
DFH					**1.000**	–0.600**	–0.096	–0.412*	–0.219	–0.515**	0.480*	–0.582**
FL						**1.000**	0.421*	0.249	0.673**	0.668**	–0.587**	0.556**
FD							**1.000**	0.438*	0.234	0.512**	–0.017	0.512**
AFW								**1.000**	0.098	0.407*	–0.121	0.762**
NFV									**1.000**	0.207	–0.381	0.572**
FT										**1.000**	0.036	0.484*
CS											**1.000**	–0.330
FYV												**1.000**

* and ** indicate significance at 5 and 1 per cent levels, respectively

VL - Vine length at last harvest; NB - Number of branches per vine; NFF - Node to first female flower; DFF - Days to first female flowering; DFH - Days to first harvest; FL - Fruit length; FD - Fruit diameter; AFW - Average fruit weight; NFV - Number of fruits per vine; FT - Flesh thickness; CS - Cavity size; FYV - Fruit yield per vine.

Table 2 : Phenotypic correlation coefficients among growth, flowering, fruit and yield traits in F_4 lines of bitter gourd.

Traits	VL	NB	NFF	DFF	DFH	FL	FD	AFW	NFV	FT	CS	FYV
VL	**1.000**	0.053	–0.404**	–0.466**	–0.473**	0.194	0.162	0.501**	0.240	0.232	–0.317*	0.620**
NB		**1.000**	–0.150	0.022	–0.113	0.359**	0.169	–0.007	0.221	0.241	0.003	0.231
NFF			**1.000**	0.620**	0.601**	–0.366**	–0.453**	–0.553**	–0.337*	–0.530**	0.268	–0.665**
DFF				**1.000**	0.825**	–0.356**	–0.050	–0.311*	–0.277*	–0.330*	0.411**	–0.471**
DFH					**1.000**	–0.394**	–0.106	–0.378**	–0.230	–0.445**	0.405**	–0.528**
FL						**1.000**	0.206	0.163	0.374**	0.481**	–0.324*	0.337*
FD							**1.000**	0.426**	0.208	0.457**	–0.036	0.476**
AFW								**1.000**	0.092	0.390**	–0.123	0.740**
NFV									**1.000**	0.197	–0.300*	0.585**
FT										**1.000**	0.047	0.450**
CS											**1.000**	–0.311*
FYV												**1.000**

* and ** indicate significance at 5 and 1 per cent levels, respectively

VL - Vine length at last harvest; NB - Number of branches per vine; NFF - Node to first female flower; DFF - Days to first female flowering; DFH - Days to first harvest; FL - Fruit length; FD - Fruit diameter; AFW - Average fruit weight; NFV - Number of fruits per vine; FT - Flesh thickness; CS - Cavity size; FYV - Fruit yield per vine.

flesh thickness, so early lines tended to have larger fruits as well. Negative associations of yield with node and days to first female flower were reported earlier by Yadav *et al*. (2008), Jatav *et al*. (2016), Nithinkumar (2018), Kishorkumar (2025) and Sahana (2025). Cavity size was negatively related to yield (rG = –0.330, rP = –0.311; significant only at the phenotypic level) and to fruit length (rG = –0.587), indicating that longer fruits in these lines had proportionately smaller seed cavities.

Since average fruit weight, vine length, number of fruits per vine, fruit length, fruit diameter and flesh thickness were positively and significantly correlated with fruit yield at both genotypic and phenotypic levels, these traits can be used as indirect selection criteria for improving yield. Node to first female flower, days to first female flowering and days to first harvest were negatively correlated with yield, so selection for early flowering at a lower node would also favour higher yield. As average fruit weight and number of fruits per vine were practically uncorrelated (rG = 0.098, rP = 0.092), both can be selected for simultaneously.

Path coefficient analysis : The direct and indirect effects at the genotypic and phenotypic levels are given in Tables 3 and 4, respectively. The residual effects were

Table 3 : Genotypic path coefficients showing direct (bold diagonal) and indirect effects of component traits on fruit yield per vine in F_4 lines of bitter gourd.

Traits	VL	NB	NFF	DFF	DFH	FL	FD	AFW	NFV	FT	CS	rG with FYV
VL	**0.184**	0.001	–0.081	–0.139	0.370	–0.002	0.045	0.281	0.146	–0.038	–0.054	0.714**
NB	0.006	**0.022**	–0.032	–0.001	0.139	–0.005	0.047	0.001	0.117	–0.036	–0.005	0.252
NFF	–0.090	–0.004	**0.164**	0.180	–0.487	0.005	–0.106	–0.301	–0.202	0.081	0.037	–0.721**
DFF	–0.099	0.000	0.115	**0.257**	–0.564	0.005	–0.008	–0.161	–0.160	0.048	0.063	–0.504**
DFH	–0.108	–0.005	0.127	0.231	**–0.629**	0.005	–0.022	–0.208	–0.112	0.069	0.071	–0.582**
FL	0.041	0.015	–0.107	–0.152	0.378	**–0.008**	0.097	0.126	0.342	–0.089	–0.087	0.556**
FD	0.036	0.005	–0.076	–0.009	0.060	–0.003	**0.230**	0.221	0.119	–0.068	–0.003	0.512**
AFW	0.102	0.000	–0.098	–0.082	0.260	–0.002	0.101	**0.504**	0.050	–0.054	–0.018	0.762**
NFV	0.053	0.005	–0.065	–0.081	0.138	–0.005	0.054	0.049	**0.508**	–0.028	–0.056	0.572**
FT	0.052	0.006	–0.100	–0.093	0.324	–0.005	0.117	0.205	0.105	**–0.133**	0.005	0.484*
CS	–0.067	–0.001	0.042	0.109	–0.302	0.005	–0.004	–0.061	–0.194	–0.005	**0.148**	–0.330

Residual effect = 0.266; rG - Genotypic correlation with fruit yield per vine; * and ** indicate significance at 5 and 1 per cent levels, respectively

0.266 and 0.336, so the eleven traits accounted for about 93 and 89 per cent of the variation in yield at the two levels, respectively.

Average fruit weight and number of fruits per vine had the highest positive direct effects on yield at both levels (genotypic 0.504 and 0.508; phenotypic 0.503 and 0.425). In each case the direct effect made up most of the correlation with yield, and the indirect effects of either trait through the other were small (0.039 to 0.050) because the two traits were nearly independent. These two traits are therefore the primary components of yield in these lines, and selection based on them is likely to be effective. Similar conclusions on the importance of fruit weight and fruit number were drawn by Singh *et al*. (2012), Pathak *et al*. (2014), Rani *et al*. (2015), Jatav *et al*. (2016), Yadagiri *et al*. (2017), Moharana *et al*. (2018), Kishorkumar (2025) and Sahana (2025) in bitter gourd.

Vine length had a low direct effect (0.184 and 0.169), and a considerable part of its correlation with yield came through average fruit weight (0.281 and 0.252). Fruit diameter had a moderate direct effect at the genotypic level (0.230), but a negligible one at the phenotypic level (0.092), with its remaining association with yield routed mainly through fruit weight (0.221 and 0.215). For fruit length the direct effect was negligible at both levels (–0.008 and –0.084) and its positive correlation with yield arose largely through number of fruits per vine (0.342 and 0.159). Flesh thickness showed a similar pattern, with a negative genotypic (–0.133) and negligible phenotypic (0.018) direct effect, and positive indirect effects through average fruit weight (0.205 and 0.197). These traits are associated with yield mainly because they are related to fruit weight or fruit number and selecting for them alone would bring little gain in yield. Similar disagreement between correlation and direct effect for fruit traits was noted by Yadav *et al*. (2013) and Jatav *et al*. (2016), who cautioned against selection based on correlations alone.

At the phenotypic level, node to first female flower, days to first female flowering and days to first harvest all had small direct effects (–0.063, 0.011 and –0.119), and their negative correlations with yield arose mainly through indirect effects via fruit weight (–0.278, –0.157 and –0.190) and fruit number (–0.143, –0.118 and –0.098). At the genotypic level, days to first harvest had a large negative direct effect (–0.629), whereas node to first female flower and days to first female flowering had positive direct effects (0.164 and 0.257) that were opposite in sign to their correlations with yield. This pattern results from the very high correlations among the three earliness traits (rG = 0.700 to 0.896). When independent variables are so closely related, path analysis cannot reliably separate their individual effects, and the phenotypic estimates are a safer guide. Both the phenotypic path coefficients and the correlations show that earliness is favourable for yield, mainly because early lines also carried more and heavier fruits. Moharana *et al*. (2018), Kishorkumar (2025) and Sahana (2025) also reported a negative effect of late maturity on fruit yield in bitter gourd.

Cavity size had a small direct effect at both levels (0.148 and –0.032) and its negative association with yield came mostly through number of fruits per vine (–0.194 and –0.128). Number of branches had a negligible

Table 4 : Phenotypic path coefficients showing direct (bold diagonal) and indirect effects of component traits on fruit yield per vine in F_4 lines of bitter gourd.

Traits	VL	NB	NFF	DFF	DFH	FL	FD	AFW	NFV	FT	CS	rG with FYV
VL	**0.169**	0.006	0.026	–0.005	0.057	–0.016	0.015	0.252	0.102	0.004	0.010	0.620**
NB	0.009	**0.119**	0.009	0.000	0.013	–0.030	0.016	–0.003	0.094	0.004	0.000	0.231
NFF	–0.068	–0.018	**–0.063**	0.007	–0.072	0.031	–0.042	–0.278	–0.143	–0.009	–0.009	–0.665**
DFF	–0.079	0.003	–0.039	**0.011**	–0.099	0.030	–0.005	–0.157	–0.118	–0.006	–0.013	–0.471**
DFH	–0.080	–0.013	–0.038	0.009	**–0.119**	0.033	–0.010	–0.190	–0.098	–0.008	–0.013	–0.528**
FL	0.033	0.043	0.023	–0.004	0.047	**–0.084**	0.019	0.082	0.159	0.009	0.010	0.337*
FD	0.027	0.020	0.029	–0.001	0.013	–0.017	**0.092**	0.215	0.088	0.008	0.001	0.476**
AFW	0.085	–0.001	0.035	–0.003	0.045	–0.014	0.040	**0.503**	0.039	0.007	0.004	0.740**
NFV	0.041	0.026	0.021	–0.003	0.028	–0.031	0.019	0.046	**0.425**	0.004	0.009	0.585**
FT	0.039	0.029	0.034	–0.004	0.053	–0.040	0.042	0.197	0.084	**0.018**	–0.002	0.450**
CS	–0.054	0.000	–0.017	0.004	–0.048	0.027	–0.003	–0.062	–0.128	0.001	**–0.032**	–0.311*

Residual effect = 0.336; rP - Phenotypic correlation with fruit yield per vine; * and ** indicate significance at 5 and 1 per cent levels, respectively

VL - Vine length at last harvest; NB - Number of branches per vine; NFF - Node to first female flower; DFF - Days to first female flowering; DFH - Days to first harvest; FL - Fruit length; FD - Fruit diameter; AFW - Average fruit weight; NFV - Number of fruits per vine; FT - Flesh thickness; CS - Cavity size; FYV - Fruit yield per vine.

genotypic direct effect (0.022) and a low phenotypic direct effect (0.119), consistent with its weak correlation with yield.

Taken together, the correlation and path analyses identify average fruit weight and number of fruits per vine as the main yield components in these F_4 lines. Vine length, fruit diameter, fruit length and flesh thickness contribute to yield mainly through these two traits and early flowering at a low node is associated with higher yield.

Conclusion

Fruit yield per vine in the F_4 lines was positively associated with average fruit weight, vine length, number of fruits per vine, fruit length, fruit diameter and flesh thickness, and negatively associated with node to first female flower, days to first female flowering and days to first harvest. Average fruit weight and number of fruits per vine had the highest direct effects on yield, while the other fruit traits influenced yield mainly through these two characters. Because fruit weight and fruit number were practically independent of each other, both can be improved together. Selection for heavier fruits, more fruits per vine and early flowering at a lower node is therefore recommended for improving fruit yield in these lines.

Acknowledgement

The first author acknowledges the Department of Science and Technology, Government of Karnataka, for the Ph.D. scholarship. The authors are grateful to the College of Horticulture, Bagalkot, for providing field facilities and to Dr. Vijaykumar Rathod, Professor and Head, Department of Vegetable Science, for his guidance during the study.

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