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Correlation and Path Co-Efficient Analysis among Yield and its Yield Attributes in Bitter Gourd (*Momordica charantia* L.)

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ABSTRACT

The present study aimed to investigate the interrelationships among yield and its component traits in 40 diverse genotypes of bitter gourd (*Momordica charantia* L.) through correlation and path coefficient analysis under a Randomized Complete Block Design with three replications. Highly significant positive genotypic and phenotypic correlations were observed between fruit yield per vine and traits such as sex ratio (0.704) and (0.726), vine length (0.690) and (0.798), primary branch count per vine (0.604) and (0.638), fruit length (0.268) and (0.265), fruit girth (0.275) and (0.300), mean fruit weight (0.423) and (0.441), fruits per vine (0.730) and (0.753) number of seeds per fruit (0.261) and (0.267), suggesting their potential as selection indices for yield improvement. Path analysis revealed that fruits per vine (0.8122), mean fruit weight (0.5686), days to first appearance of female flower (0.1294), days to first picking (0.1268), total soluble solids (0.1138), primary branch count per vine (0.1116), vine length (0.0586), ascorbic acid content (0.0467) and node of first staminate flower emergence (0.0399) showed high magnitude of positive direct effect on fruit yield per vine. The findings suggest that direct selection based on key traits especially fruits per vine, mean fruit weight, and early flowering can effectively enhance yield in bitter gourd. The study concludes that integrating correlation and path analyses provides a robust framework for identifying yield-contributing traits and can significantly support breeding strategies aimed at yield optimization in bitter gourd.

Keywords Bitter gourd, Phenotypic correlation, Genotypic correlation, Path analysis.

INTRODUCTION

Bitter gourd is a commercial cucurbitaceous vegetable grown in India during the warm season for its tender fruits. The fruit contains high nutritional value, including ascorbic acid and iron. Its extract contains

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antioxidant, antimicrobial, antiviral, antihepatotoxic, antiulcerogenic, and blood sugar-lowering properties. The bitter taste of the fruit is primarily attributed to the presence of cucurbitacin-like alkaloids, notably momordicine, along with triterpene glycosides. India is the third-most exported vegetable after onion and okra. The major growing states in India are Karnataka, Kerala, Maharashtra, Andhra Pradesh, Tamil Nadu, and Chattisgarh. The total vegetable production in India is estimated to be about 102.92 million tonnes, with an annual production of 1.205 million tonnes.

Yield is a polygenic trait with strong environmental interaction; thus, selection based solely on yield may constrain genetic gain. Effective improvement can be achieved through selecting various yield component characters. Correlation and path coefficient analyses elucidate the strength and direction of relationships among traits, quantifying both direct and indirect effects on yield. While correlation reveals the degree of association between yield and its components, path analysis partitions these associations to identify traits exerting a direct influence, thereby guiding effective selection strategies in crop improvement programs.

MATERIALS AND METHODS

The experimental study was conducted in Sivapuri village, located within the Chidambaram taluk which is located at 11º24' North latitude, 79º41' East longitude and at an altitude of ± 5.79 m above mean sea level in the Cuddalore district of Tamil Nadu, India. The experimental material comprised 40 genotypes of bitter gourd having diverse fruit and other economic traits. The experiment was laid out in a Randomized Block Design with three replications. Data were recorded from five randomly selected plants per genotype in each replication. Genotypic and phenotypic correlation coefficients were computed using variance and covariance estimates, following the method of Al-Jibouri *et al.* (1958). The direct and indirect effect of component characters on fruit yield per vine were calculated through path co-efficient analysis as suggested by Wright (1921) and elaborated by Dewey and Lu (1959) at both phenotypic and genotypic levels. Observations were recorded on sixteen traits viz., days to first male flower, days to first female flower, node of first staminate flower emergence, node number of first female flower, sex ratio, vine length, primary branch count per vine, days to first fruit harvest, fruit length, fruit girth, mean fruit weight, number of fruits per vine, number of seeds per fruit, total soluble solids, ascorbic acid content and fruit yield per vine.

RESULTS AND DISCUSSION

Correlation studies

Breeding approaches cannot easily separate physiological associations of characters from genetic correlations. To improve yield, selection should focus on different components, separating phenotypic and genotype correlations to explain environmental influences on heritable expression.

In general, the genotypic correlations were higher than the phenotypic correlations indicating that the phenotypic correlation expression was decreased under environmental effects, although there is a strong inherent association between diverse traits.

According to Wigan and Mather (1942) and Sprague (1966), the strong positive correlation observed between a trait and yield can be ascribed to either genetic linkage or pleiotropic effects. However, in all cases, more reliance may be placed on genotypic correlation with yield and yield components. In the present analysis, highly significant and positive correlation of fruit yield per vine both at phenotypic and genotypic level were observed with sex ratio (0.704) and (0.726), vine length (0.690) and (0.798), primary branch count per vine (0.604) and (0.638), fruit length (0.268) and (0.265), fruit girth (0.275) and (0.300), mean fruit weight (0.423) and (0.441), fruits per vine (0.730) and (0.753), number of seeds per fruit (0.261) and (0.267), but significant and negative correlation with days to first appearance of male flower (-0.544) and (-0.559), days to first appearance of female flower (-0.615) and (-0.634), node number of first male flower (-0.464) and (-0.503), node number of first female flower (-0.600) and (-0.630) and days to first picking (-0.711) and (-0.734) respectively, indicating mutual association of these characters (Table 1). The correlation analysis suggests that fruit yield in bitter

Table 1. Phenotypic (rp) and genotypic (rg) correlation coefficient between sixteen characters in bitter gourd genotypes.

Characters		DFAMF	DFAFF	NFSFE	NFPFE	SR	VL	NPB/V	DFP
DFAMF	rp	1.000	0.475**	0.756**	0.488**	-0.538**	-0.274*	-0.637**	0.347*
	rg	1.000	0.480**	0.793**	0.502**	-0.542**	-0.304*	-0.658**	0.350*
DFAFF	rp		1.000	0.480**	0.739**	-0.518**	-0.492**	-0.426**	0.410**
	rg		1.000	0.502**	0.757**	-0.521**	-0.572**	-0.438**	0.412**
NFSFE	rp			1.000	0.568**	-0.484**	0.319**	-0.644**	0.379**
	rg			1.000	0.568**	-0.500**	-0.356*	-0.680**	0.395**
NFPFE	rp				1.000	-0.470**	-0.452**	-0.410**	0.228
	rg				1.000	-0.482**	-0.527**	-0.436**	0.234
SR	rp					1.000	0.538	0.490**	-0.406**
	rg					1.000	0.614**	0.502**	-0.408**
VL	rp						1.000	0.422**	-0.524**
	rg						1.000	0.521**	-0.604**
NPB/V	rp							1.000	-0.496**
	rg							1.000	-0.513**
DFP	rp								1.000
	rg								1.000
FL	rp								
	rg								
FG	rp								
	rg								
MFW	rp								
	rg								
NF/V	rp								
	rg								
NS/F	rp								
	rg								
TSS	rp								
	rg								
AAC	rp								
	rg								
FY/V	rp								
	rg								

Table 1. Continued.

Characters		FL	FG	MFW	NF/V	NS/F	TSS	AAC	FY/V
DFAMF	rp	-0.383**	-0.178	-0.390**	-0.329**	-0.162	-0.017	0.042	-0.544**
	rg	-0.388**	-0.180	-0.394**	-0.331*	-0.163	-0.014	0.043	-0.559**
DFAFF	rp	-0.039	-0.124	-0.145	-0.554**	-0.009	0.024	-0.210	-0.615**
	rg	-0.042	-0.126	-0.148	-0.561**	-0.009	0.029	-0.212	-0.634**
NFSFE	rp	-0.241	-0.285*	-0.280*	-0.298*	-0.141	-0.048	-0.084	-0.464**
	rg	**-0.257**	-0.297	-0.280	-0.313*	-0.148	0.043	-0.088	-0.503**
NFPFE	rp	-0.140	-0.249	-0.257	-0.395**	-0.165	-0.133	-0.163	-0.600**
	rg	-0.157	-0.260	-0.267	-0.408**	-0.168	-0.133	-0.170	-0.630**
SR	rp	0.068	-0.079	0.033	0.819**	-0.075	-0.105	0.153	0.704**
	rg	0.069	-0.081	0.032	0.824**	-0.075	-0.108	0.153	0.726**
VL	rp	0.074	0.142	0.250	0.546**	0.046	-0.067	0.120	0.690**
	rg	0.086	0.177	0.274	0.631**	0.043	-0.081	0.139	0.798**
NPB/V	rp	0.235	0.218	0.316*	0.392**	0.171	-0.089	0.026	0.604**
	rg	0.253	0.225	0.323*	0.402**	0.175	-0.088	0.028	0.638**
DFP	rp	-0.322*	-0.343*	-0.471 **	-0.458**	-0.337*	0.127	-0.018	-0.711**
	rg	-0.327*	-0.352*	-0.477**	-0.461**	-0.339*	0.132	-0.018	-0.734**
FL	rp	1.000	0.498**	0.760**	-0.192	0.792**	0.208	0.239	0.268*
	rg	1.000	0.520**	0.785**	-0.195	0.808**	0.224	0.245	0.265*
FG	rp		1.000	0.758**	-0.214	0.822**	0.165	0.075	0.275*

Table 1. Continued.

Characters		FL	FG	MFW	NF/V	NS/F	TSS	AAC	FY/V
	rg		1.000	0.780**	-0.220	0.845**	0. 172	0.074	0.300*
MFW	rp			1.000	-0.202	0.836**	0.215	0.065	0.423**
	rg			1.000	-0.206	0.848**	0.225	0.067	0.441**
NF/V	rp				1.000	-0.263	-0.233	0.099	0.730**
	rg				1.000	-0.266	-0.241	0.098	0.753**
NS/F	rp					1.000	0.300*	0.166	0.261*
	rg					1.000	0.306*	0.167	0.267*
TSS	rp						1.000	0.226	0.022
	rg						1.000	0.229	0.029
AAC	rp							1.000	0.142
	rg							1.000	0.149
FY/V	rp								1.000
	rg								1.000

*- Significant at 5% level, **- Significant at 1% level.
DFAMF - Days to first appearance of male flower, DFAFF- Days to first appearance of female flower, NFSFE - Node of first staminate flower emergence, NFPFE - Node of first pistillate flower emergence, SR - Sex ratio, VL - Vine length, PBC/V - Primary branch count per vine, DFP - Days to first picking, FL - Fruit length, FG - Fruit girth, MFW - Mean fruit weight, F/V - Fruits per vine, NS/F -Number of seeds per fruit, TSS - Total soluble solids, AAC - Ascorbic acid content, FY/V- Fruit yield per vine.

gourd can be enhanced by selecting and manipulating one or more of these traits, as also indicated by the findings of Khan *et al.* (2015), Singh *et al.* (2015), Sowmya *et al.* (2019) and Ziaul *et al.* (2019) in bitter gourd.

The intercorrelation among yield components affirms that sex ratio was positively and significantly associated with vine length (0.614), primary branch count per vine (0.502) and fruits per vine (0.824) (Rani *et al.* 2015 and Gowda *et al*. 2020 in bitter gourd). Vine length exhibited significant positive correlation with yield through primary branch count per vine (0.521) and fruits per vine (0.631). It is evident that longer vine length induced more number of primary branches combined with high sex ratio resulted in high yield and high fruit quality. Primary branch count per vine exhibited significant positive correlation with mean fruit weight (0.323) and fruits per vine (0.402). Similar observations were also made by Gupta *et al*. (2015), Yadagiri *et al.* (2017), Ziaul *et al.* (2019), Alekar *et al*. (2019) and Naik (2020) in bitter gourd. These associations indicated that the selection of these component characteristics simultaneously could increase bitter gourd yield.

Similarly, fruit length showed significant positive association with fruit girth (0.520), mean fruit weight (0.785) and number of seeds per fruit (0.808). Fruit girth expressed significant and positive correlation with mean fruit weight (0.780) and number of seeds per fruit (0.845). The results revealed that increased fruit girth simultaneously improves seed yield, fruit weight, and yield per vine.

Further, mean fruit weight was positively and significantly correlated with number of seeds per fruit (0.848). Similar findings were also reported by Subhasmita (2015), Priyanka *et al.* (2018) and Naik (2020) in bitter gourd. Number of seeds per fruit exhibited significant positive correlation with yield through total soluble solids (0.306).

On the contrary, days to first appearance of male flower had significant negative correlation with sex ratio (-0.542), vine length (-0.304), primary branch count per vine (-0.658), fruit length (-0.388), mean fruit weight (-0.394) and fruits per vine (-0.331). Days to first appearance of female flower showed significant negative correlation through sex ratio (-0.521), vine length (-0.572), primary branch count per vine (-0.438) and per vine (-0.561).

Likewise, node of first staminate flower emergence and node number of first female flower exhibited significant and negatively associated with sex ratio (-0.500 and -0.482), vine length (-0.356 and -0.527), primary branch count per vine (-0.680 and -0.436)

Table 2. Path coefficient analysis between sixteen characters in bitter gourd genotypes.

Characters	DFAMF	DFAFF	NFSFE	NFPFE	SR	VL	PBC/V	DFFH
DFAMF	**-0.0457**	0.0622	0.0316	-0.1031	0.0733	-0.0178	-0.0734	-0.0445
DFAFF	-0.0219	**0.1294**	0.0200	-0.1555	0.0704	-0.0335	-0.0489	-0.0523
NFSFE	-0.0363	0.0650	**0.0399**	-0.1166	0.0675	-0.0209	-0.0759	-0.0502
NFPFE	-0.0229	0.0980	0.0226	**-0.2053**	0.0652	-0.0309	-0.0487	-0.0297
SR	0.0248	-0.0675	-0.0200	0.0991	**-0.1350**	0.0360	0.0561	0.0517
VL	0.0139	-0.0740	-0.0142	0.1083	-0.0830	**0.0586**	0.0582	0.0766
PBC/V	0.0301	-0.0567	-0.0271	0.0896	-0.0679	0.0306	**0.1116**	0.0651
DFFH	-0.0160	0.0534	0.0158	-0.0481	0.0551	-0.0354	-0.0573	**0.1268**
FL	0.0178	-0.0055	-0.0102	0.0323	-0.0094	0.0051	0.0283	0.0416
FG	0.0083	-0.0164	-0.0119	0.0535	0.0110	0.0104	0.0252	0.0447
MFW	0.0180	-0.0192	-0.0112	0.0549	-0.0044	0.0161	0.0361	0.0606
F/V	0.0152	-0.0726	-0.0125	0.0838	-0.1114	0.0370	0.0450	0.0585
NS/F	0.0075	-0.0012	-0.0059	0.0345	0.0102	0.0026	0.0196	0.0431
TSS	0.0006	0.0038	0.0017	0.0274	0.0146	-0.0047	-0.0099	-0.0167
AAC	-0.0020	-0.0275	-0.0035	0.0349	-0.0207	0.0082	0.0032	0.0024

Table2. Continued.

Characters	FL	FG	MFW	F/V	NS/F	TSS	AAC	FY/V
DFAMF	0.0411	0.0003	-0.2245	-0.2694	0.0107	-0.0016	0.0020	-0.5589**
DFAFF	0.0045	0.0002	-0.0843	-0.4560	0.0006	0.0033	-0.0099	0.6340**
NFSFE	0.0272	0.0006	-0.1594	-0.2547	0.0097	0.0050	-0.0041	-0.5033**
NFPFE	0.0166	0.0005	-0.1521	0.3316	0.0110	-0.0152	-0.0079	0.6306**
SR	-0.0073	0.0002	0.0185	0.6699	0.0049	-0.0123	0.0072	0.7263**
VL	-0.0092	-0.0003	0.1560	0.5126	-0.0029	-0.0092	0.0065	0.7980**
PBC/V	-0.0268	-0.0004	0.1837	0.3272	-0.0114	-0.0101	0.0013	0.6388**
DFFH	0.0347	0.0007	-0.2717	-0.3748	0.0221	0.0150	-0.0009	-0.7342**
FL	**-0.1057**	-0.0010	0.4468	-0.1587	-0.0527	0.0255	-0.0115	0.2653*
FG	-0.0551	**-0.0019**	0.4438	-0.1794	-0.0551	0.0196	0.0035	0.3001*
MFW	-0.0830	-0.0015	**0.5686**	-0.1673	-0.0553	0.0256	0.0031	0.4412**
F/V	0.0207	0.0004	-0.1171	**0.8122**	0.0174	-0.0275	0.0046	0.7536**
NS/F	-0.0855	-0.0016	0.4827	-0.2163	**-0.0652**	0.0348	0.0078	0.2671*
TSS	-0.0237	-0.0003	0.1281	-0.1961	-0.0200	**0.1138**	0.0107	0.0294
AAC	-0.0259	-0.0001	0.0381	0.0803	-0.0109	0.0261	**0.0467**	0.1491

Residual effect = 0.0825, Bold values indicates direct effects.
DFAMF - Days to first appearance of male flower, DFAFF- Days to first appearance of female flower, NFSFE - Node of first staminate flower emergence, NFPFE - Node of first pistillate flower emergence, SR -Sex ratio, VL-Vine length, PBC/V - Primary branch count per vine, DFFH -Days to first fruit harvest, FL-Fruit length, FG-Fruit girth, MFW-Mean fruit weight, F/V- Fruits per vine, NS/F -Number of seeds per fruit, TSS- Total soluble solids, AAC -Ascorbic acid content, FY/V-Fruit yield per vine.

and fruits per vine (-0.313 and -0.408). Days to first picking showed significant negative correlation with fruit length (-0.327), fruit girth (-0.352), mean fruit weight (-0.477), number of fruits per vine (-0.461) and number of seeds per fruit (-0.339).

Based on the correlation analysis, both genotypic and phenotypic correlations revealed significant positive associations of sex ratio, vine length, primary branch count per vine, and number of fruits per vine with fruit yield, indicating their potential utility as effective selection criteria in bitter gourd improvement programs.

Path coefficient analysis

Path analysis helps examine the relative contributions (both direct and indirect) of independent variables towards a dependent variable. Assessing the magnitude and nature of direct and indirect influences of yield-attributing traits on overall productivity is crucial for identifying superior genotypes. The data on path coefficient analysis showing direct and indirect effects of significant characters over fruit yield per plant is tabulated in Table 2.

The path analysis made in the present study revealed that fruits per vine (0.8122), mean fruit weight (0.5686), days to first appearance of female flower (0.1294), days to first fruit harvest (0.1268), total soluble solids (0.1138), primary branch count per vine (0.1116), vine length (0.0586), ascorbic acid content (0.0467) and node of first staminate flower emergence (0.0399) showed high magnitude of positive direct effect on fruit yield per vine. On the contrary, fruit girth (-0.0019), days to first appearance of male flower (-0.0457), number of seeds per fruit (-0.0652), fruit length (-0.1057), sex ratio (-0.1350) and node number of first female flower (-0.2053) exhibited negative direct effect on fruit yield per vine.

Earlier workers also substantiated the higher positive direct effect of mean fruit weight and the fruits per vine (Singh and Singh 2015, Priyanka *et al.* 2018 and Rahman *et al.* 2021 in bitter gourd). The direct selection of fruit length and mean fruit weight had a high contribution to yield per vine as reported by Kumari *et al*. (2018) and Sowmya *et al.*(2019). Fruits per vine and mean fruit weight manifested maximum positive direct effect on the fruit yield was also recorded by Gupta *et al.* (2015), Khan *et al.* (2015), Sidhu and Mamta (2016), Maurya *et al.* (2019) and Naik (2020) in bitter gourd.

Maximum positive indirect effects on fruit yield per vine was exhibited by sex ratio (0.6699) via fruits per vine followed by sex ratio (0.5126) through number of fruits per vine, number of seeds per fruit (0.4827) via mean fruit weight, fruit length (0.4468) through mean fruit weight, fruit girth (0.4438) though mean fruit weight, node number of first female flower (0.3316) via number of fruits per vine, primary branch count per vine (0.3272) through number of fruits per vine, primary branch count per vine (0.1837) through mean fruit weight, vine length (0.1560) through mean fruit weight, TSS (0.1281) via mean fruit weight, vine length (0.1083) through node number of first female flower, node number of first female flower (0.980) through days to first fruit harvest, fruits per vine (0.0838) via node number of first female flower and ascorbic acid content (0.0803) through number of fruits per vine, respectively.

Maximum negative indirect effects on fruit yield per vine were shown by days to first female flower(-0.4560) through fruits per vine followed by days to first picking (-0.3748) via number of fruits per vine, days to first picking (-0.2717) through mean fruit weight, days to first appearance of male flower (-0.2694) via number of fruits per vine, node of first staminate flower emergence (-0.2547) through number of fruits per vine, days to first appearance of male flower (-0.2245) via mean fruit weight, number of seeds per fruit (-0.2163) through number of fruits per vine, TSS (-0.1961) through number of fruits per vine, fruit girth (-0.1794) via number of fruits per vine, mean fruit weight (-0.1673) through number of fruits per vine, node of first staminate flower emergence (-0.1594) via mean fruit weight and fruit length (-0.1587) through number of fruits per vine, respectively. Similar findings were also reported by Ziaul *et al.* (2019).

The residual effect observed in the current investigation was very low (0.0825), indicating almost 92% of the variation in total fruit yield per vine was attributable to factors considered in this study.

From the above result of path analysis, it indicated that fruits per vine and mean fruit weight had the highest direct positive effects on yield, identifying them as key components for direct selection to enhance productivity in bitter gourd genotypes.

CONCLUSION

The present study highlights the significance of correlation and path coefficient analysis in identifying key yield-contributing traits in bitter gourd. Traits such as number of fruits per vine, mean fruit weight, vine length, primary branch count, and early flowering exhibited strong positive correlations and direct effects on fruit yield per vine. The high explanatory power of these traits, as indicated by the low residual effect, suggests their reliability for use in selection strategies. Therefore, prioritizing these attributes in breeding programs could effectively enhance yield potential in bitter gourd genotypes. The study provides a valuable framework for trait-based selection, supporting more precise and efficient crop improvement efforts.

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