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Character association studies in F_3 segregating population of bitter gourd (*Momordica charantia* L.)

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Abstract
The present study was conducted at Department of Vegetable Science, College of Agriculture, OUAT, Bhubaneswar, Odisha, India during late kharif season of 2017. The objective was to study the character association and path coefficient analysis in F_3 segregating population of bitter gourd. Fourteen F_3 segregants along with eight parents were evaluated by adopting RBD with three replications. The genotypes were evaluated for 19 parameters including, vegetative growth, flowering, fruit yield and yield attributing as well as fruit quality parameters. At phenotypic level, green fruit yield vine^{-1} was positively and significantly correlated with days to last fruit harvest (0.26) and fruits vine^{-1} (0.43) while at genotypic level, positive significant correlation with sex ratio (0.25), fruit weight (0.33), number of node bearing 1st male flower (0.39), days to last fruit harvest (0.46), green fruits vine^{-1} (0.89) and primary branches vine^{-1} (0.92). Similarly, fruits vine^{-1}, number of nodes bearing 1st male flower, fruit weight, days to initiation of 1st female flower, days to last fruit harvest, primary branches vine^{-1} and fruit girth in order of merits imposed positive direct effect on green fruit yield vine^{-1}. Hence, the characters can be considered for bitter gourd improvement programme.

Keywords: Bitter gourd, correlation coefficient, path analysis, F_3 segregants

1. Introduction
Bitter gourd (*Momordica charantia* L.) or Balsam pear belongs to the family Cucurbitaceae, is one of the most important vegetable grown extensively for its bitter immature fruits. Correlations are helpful to ascertain the real components of yield which is a complex character. Direct selection for yield is often misleading as yield is polygenically controlled and also subjected to the effect of fluctuating environment. Efficiency of selection in any breeding programme is enhanced and mainly depends on the knowledge of association of characters. Correlation coefficient is a statistical measure which is used to find out the size and direction of relationship between two or more variables and it measures the degree of association either in positive or negative direction. Phenotypic correlation is the observable correlation between two variables while genotypic correlation is inherent association between two variables; it may be either due to pleiotropic action of gene, linkage or both or due to developmentally induced relationships.
Path coefficient is the measure of direct influence of one variable upon another which permits the separation of correlation coefficient into component of direct and indirect effects. The use of path coefficient analysis requires a cause and effect situation among variables. Information on correlation and path coefficient may be advantageously used for the identification of characters which are useful indices for consideration in the improvement of yield. So, the study was conducted to examine the nature and magnitude of character association and assess the direct and indirect effects of different component traits on yield through path coefficient analysis.

2. Materials and Methods
The present study to assess character association in F_3 segregants of bitter gourd was carried out during *late kharif* season of the year 2017-18 at Department of Vegetable Science, College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar. The experimental plant material comprised of fourteen F_3 segregants along with their eight parents and the seeds were collected from F_2 crop.

These lines were evaluated through randomized block design (RBD) with three replications. Seeds were soaked overnight to obtain better germination and seed treatment was done using GA_3 at 30ppm. Seedlings were raised in polybags and transplanted 25 days after sowing. Four plants per plot was grown at spacing of 1.75×1.25m^2. The recommended cultural practices and input requirements were followed to raise healthy crop. Observations were recorded from each plant and the mean data was computed.

3. Results

The association of green fruit yield vine^{-1} with other component characters was studied by using correlation analysis whereas the direct and indirect components were analysed by using the path coefficient analysis. The data revealed the significant phenotypic correlation which ranged from 0.24 (between sex ratio and number of nodes bearing 1st male flower) to 0.59 (between fruit length and fruit weight). Out of 91 estimates of phenotypic correlation with green fruit yield vine^{-1}, only 25 estimates were found significant, among which 23 were positively significant, 2 were negatively significant and remaining were recorded as non-significant. Similarly, genotypic value ranged from -0.24 (between number of node bearing 1st female flower and days to 1st male flower initiation) to 1.15 (between fruits vine^{-1} and primary branches vine^{-1}). Out of 91 genotypic correlation estimates, 56 were significant from which 49 were positive and 7 were negative estimates all the remaining values were recorded as non-significant.

3.1 Correlation of fruit yield with other yield components

At phenotypic level, green fruit yield vine^{-1} was observed to be correlated positively and significantly with days to last harvest (0.26) and fruits vine^{-1} (0.43). However, it was positive and non-significant for all other characters like days to 1st female flower appearance, number of nodes bearing 1st male flower, number of nodes bearing 1st female flower, fruit length, fruit girth, vine length and primary branches vine^{-1} in the present study. Similarly, at genotypic level, however, green fruit yield vine^{-1} was found to have positive and significant correlation with sex ratio (0.25), number of node bearing 1st male flower (0.39), fruit weight (0.33), days to last fruit harvest (0.46), primary branches vine^{-1} (0.92) and green fruits vine^{-1} (0.89). The correlation of green fruit yield vine^{-1} with fruit length, fruit girth and vine length were positive but non-significant.

3.2 Correlation among yield components

Sex ratio showed positively significant correlation with almost all parameters except days to 1st male flower initiation and days to 1st female flower initiation at genotypic level. However, at phenotypic level, it showed significant positive correlation with characters like fruit length (0.39), fruit weight (0.44), days to last fruit harvest (0.32) and vine length (0.38). Significantly positive correlation at both phenotypic (0.36) and genotypic level (0.56) was noticed for days to 1st male flower initiation with only days to 1st female flower initiation. Days to 1st female flower appearance showed positive significant correlation with number of node bearing 1st female flower (0.29), number of node bearing 1st male flower (0.26), days to last fruit harvest (0.33) and vine length (0.64) at genotypic level and significant negative correlation was noticed with fruits vine^{-1} (-0.36). However, at phenotypic level significant correlation was not observed. Number of nodes bearing 1st female flower showed significantly positive correlation with number of nodes bearing 1st male flower (0.53) and fruit length (0.27) at phenotypic level. Similar trend was also noticed at genotypic level with number of nodes bearing 1st male flower (0.82), fruit length (0.46), fruit girth (0.41), days to last fruit harvest (0.32), vine length (0.56) and number of primary branches vine^{-1} (0.29). However, significantly negative correlation was observed between numbers of node bearing female flower with green fruits vine^{-1} at genotypic level. Significant positive correlation was noticed for number of nodes bearing 1st male flower with all the parameters except with fruits vine^{-1} at genotypic level. However, at phenotypic level similar trend was noticed only with fruit length (0.45). Fruit length showed significantly positive correlation with fruit girth (0.56), fruit weight (0.59), days to last fruit harvest (0.45) and vine length (0.53) at phenotypic level. Characters like fruit girth (0.79), fruit weight (0.84), days to last fruit harvest (0.62), vine length (0.81) and primary branches vine^{-1} (0.24) were found to be significantly correlated with fruit length at genotypic level. Fruit girth showed positive and significant correlation with fruit weight (0.39), days to last fruit harvest (0.28) and vine length (0.28) at phenotypic level. Similar trend was shown at genotypic level for fruit weight (0.62), days to last fruit harvest (0.31) and vine length (0.90). But significantly negative correlation was noticed with fruits vine^{-1} (-0.49) and primary branches vine^{-1} (-0.31) and rest of the characters were non-significant. Average fruit weight of bitter gourd showed positively significant correlation at both genotypic and phenotypic level with days to last fruit harvest (0.73 and 0.39), vine length (0.51 and 0.93), respectively. However, positive significant correlation at genotypic level was observed between fruit weight with fruits vine^{-1} (0.47) and primary branches vine^{-1} (0.61). The rest other characters were found non-significant.

Fruits vine^{-1} was found positively and significantly correlated at genotypic and phenotypic level with days to last fruit harvest (0.33, 0.35) and primary branches vine^{-1} (0.29 and 0.91) respectively. Rest all other characters were found non-significant. Days to last fruit harvest showed positive significant correlation with vine length (0.35) at phenotypic level. Similar trend was noticed with characters like vine length (0.85) and primary branches vine^{-1} (0.44). Vine length showed significantly positive result with primary branches vine^{-1} (0.47) at genotypic level only. Similar trend was noticed between primary branches vine^{-1} and green fruit yield (0.92). None of them showed significance at phenotypic level.

3.3 Path analysis

The correlation of yield with other 12 characters and their importance in yield assessment is presented in table 2. The results on phenotypic path analysis of green fruit yield vine^{-1} of bitter gourd with other 12 important traits studied in the present investigation, revealed that maximum direct effect on green fruit yield vine^{-1} was with green fruits vine^{-1} (0.311) closely followed by number of node bearing 1st male flower (0.297) than other traits. Rest of the traits having positive direct effect with green fruit yield in decreasing order were fruit weight (0.150), days to 1st female flower initiation (0.149), days to last fruit harvest (0.109), primary branches vine^{-1} (0.108) and fruit girth (0.090). Similarly, negative direct path to green fruit yield vine^{-1} in bitter gourd was observed with traits like sex ratio (-0.032), days to 1st male flower initiation (-0.081), number of nodes bearing 1st female flower (-0.124), fruit length and vine length (-0.001).

Table 1: Correlation coefficients among 13 characters of 22 breeding lines of bitter gourd at genotypic and phenotypic level

Character	2	3	4	5	6	7	8	9	10	11	12	13
1	-0.08 -0.06	0.13 -0.04	0.27* 0.13	0.50** 0.24*	0.49** 0.39**	0.34* 0.23	0.65* 0.44**	0.38** 0.15	0.49** 0.32*	0.64** 0.38**	0.32* 0.22	0.25* 0.12
2		0.56** 0.30*	-0.24* -0.13	-0.13 0.07	0.08 0.07	0.21 0.03	-0.10 0.07	-0.62** -0.33*	-0.33* -0.32*	0.12 0.07	-0.11 -0.14	-0.19 -0.16
3			0.29* 0.13	0.26* 0.19	0.10 0.04	0.03 0.01	0.11 -0.15	-0.36** -0.18	0.33* -0.05	0.64** 0.12	0.08 0.09	-0.19 0.08
4				0.82** 0.53**	0.46** 0.27*	0.41** 0.03	0.19 0.02	-0.29* -0.07	0.32* 0.16	0.56** 0.17	0.29* 0.03	0.07 0.01
5					0.67** 0.45**	0.88** 0.22	0.59** 0.04	0.01 0.08	0.37** 0.20	0.77** 0.21	0.25* -0.02	0.39** 0.21
6						0.80** 0.56**	0.84** 0.59**	-0.09 0.01	0.62** 0.45**	0.81** 0.53**	0.24* 0.15	0.21 0.05
7							0.62** 0.39**	-0.49** -0.10	0.31* 0.28*	0.90** 0.28*	-0.31* -0.07	0.18 0.12
8								0.47** 0.06	0.73** 0.39**	0.93** 0.51**	0.61** 0.21	0.33* 0.10
9									0.33* 0.35**	-0.02 -0.11	0.91** 0.29*	0.89** 0.43**
10										0.85** 0.35**	0.44** 0.15	0.46** 0.26*
11											0.47** 0.11	0.09 0.03
12												0.92** 0.22

*Significant at 5% level of significance
**Significant at 1% and 5% level of significance
Figures in bold letters indicate GCV
1. Sex ratio, 2. Days to 1st male flower initiation, 3. Days to 1st female flower initiation, 4. No. of node bearing 1st female flower, 5. No. of node bearing 1st male flower, 6. Fruit length, 7. Fruit girth, 8. Fruit weight, 9. Fruits vine^{-1}, 10. Days to last fruit harvest, 11. Vine length, 12. Primary branches vine^{-1}, 13. Fruit yield

Table 2: Direct and indirect effects of component traits on yield on 22 breeding lines of bitter gourd at phenotypic level for 13 characters

Character	1	2	3	4	5	6	7	8	9	10	11	12
1	-0.032	0.002	0.001	-0.004	-0.008	-0.013	-0.007	-0.014	-0.005	-0.010	-0.012	-0.007
2	0.005	-0.081	-0.025	0.011	-0.005	-0.006	-0.002	-0.006	0.027	0.026	-0.006	0.012
3	-0.006	0.045	0.149	0.020	0.028	0.006	-0.001	-0.022	-0.027	-0.007	0.017	0.014
4	-0.017	0.017	-0.016	-0.124	-0.065	-0.033	-0.003	-0.002	0.008	-0.019	-0.021	-0.004
5	0.071	0.020	0.056	0.156	0.297	0.133	0.065	0.013	0.024	0.061	0.062	-0.005
6	-0.093	-0.017	-0.010	-0.064	-0.107	-0.239	-0.134	-0.141	0.000	-0.108	-0.126	-0.035
7	0.020	0.003	0.000	0.003	0.020	0.051	0.090	0.035	0.009	0.025	0.026	-0.006
8	0.067	0.011	-0.022	0.002	0.007	0.089	0.059	0.150	0.009	0.058	0.077	0.032
9	0.046	-0.103	-0.057	-0.021	0.025	0.000	0.031	0.020	0.311	0.109	-0.034	0.091
10	0.035	-0.035	-0.005	0.017	0.022	0.050	0.031	0.043	0.038	0.109	0.038	0.017
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	0.000
12	0.023	-0.015	0.010	0.003	-0.002	0.016	-0.007	0.023	0.032	0.016	0.012	0.108
13	0.119	-0.156	0.081	0.000	0.213	0.054	0.120	0.098	0.427	0.260	0.031	0.216

R Square = 0.2811, Residual Effect = 0.8479
1. Sex ratio, 2. Days to 1st male flower initiation, 3. Days to 1st female flower initiation, 4. No. of node bearing 1st female flower, 5. No. of node bearing 1st male flower, 6. Fruit length, 7. Fruit girth, 8. Fruit weight, 9. Fruits vine^{-1}, 10. Days to last fruit harvest, 11. Vine length, 12. Primary branches vine^{-1}, 13. Fruit yield

Sex ratio showed negative direct effect (-0.032) with green fruit yield vine^{-1} and exhibited indirect negative effects through characters like fruit length (-0.013), vine length (-0.012) and average fruit weight (-0.014). However, characters like days to 1st male flower initiation (0.002) and days to 1st female flower initiation (0.001) showed lower indirect positive effect. Direct negative effect of character, days to 1st male flower initiation (-0.081) was noticed due to indirect negative effects of days to 1st female flower initiation (-0.025), number of node bearing 1st male flower (-0.005), fruit length, average fruit weight and vine length (-0.006).On the other hand, rest of the characters showed lower positive indirect effects. Days to 1st female flower initiation showed positive direct effect (0.149) and exhibited indirect positive effect via days to 1st male flower initiation (0.045), number of node bearing 1st female flower (0.020), number of node bearing 1st male flower (0.028), fruit length (0.006), vine length (0.017) and primary branches vine^{-1} (0.014). Rest all other characters exhibited negative indirect effect. Number of node bearing 1st female flower showed negative direct effect (-0.124) and exhibited indirect negative effect via sex ratio (-0.017), days to 1st female flower initiation (-0.016), number of node bearing 1st male flower (-0.065), fruit length (-0.033), fruit girth (-0.003), average fruit weight (-0.002), days to last fruit harvest (-0.019), vine length (-0.021) and primary branches vine^{-1} (-0.004). Only 2 characters such as days to 1st male flower initiation (0.017) and fruits vine^{-1} (0.008) showed positive indirect effect.

Positive direct effect was noticed in number of node bearing 1st male flower (0.297) via higher indirect positive effects of

characters like number of node bearing 1st female flower (0.156) and fruit length (0.133). However, lower positive indirect effect was noticed with all other characters except primary branches vine-1 (-0.005). Fruit length showed higher direct negative effect (-0.239) exhibited via average fruit weight (-0.141), fruit girth (-0.134) and vine length (-0.126). Similar effect was noticed with all characters but with lower effect. Fruit girth showed positive direct effect (0.090) exhibited via higher indirect positive effect of characters like fruit length (0.051), average fruit weight (0.035), days to last fruit harvest (0.025) and vine length (0.026). Indirect positive effect was noticed with all the characters except primary branches vine-1(-0.006).Direct positive effect of average fruit weight (0.150) exhibited via indirect positive effect of fruit length (0.089), vine length (0.077), sex ratio (0.067), fruit girth (0.059) and days to last fruit harvest (0.058). However, all other characters showed positive but lower indirect effect except days to 1st female flower initiation (-0.022).

Fruits vine-1 had the highest positive direct effect of 0.311 on green fruit yield vine-1. Highest direct effect was mainly resulted by positive indirect effect of days to last fruit harvest (0.109), primary branches vine-1 (0.091), sex ratio (0.046), fruit girth (0.031), number of nodes bearing 1st male flower (0.025) and average fruit weight (0.020). Rest all other characters exhibited negative indirect effect. Days to last fruit harvest showed positive direct effect (0.109) exhibited via the indirect positive effects of fruit length (0.050), average fruit weight (0.043), fruits vine-1 and vine length (0.038), sex ratio (0.035), fruit girth (0.031) and number of node bearing 1st male flower (0.022). On the other hand, characters such as days to 1st male flower initiation (-0.035) and days to 1st female flower initiation (-0.005) showed negative indirect effect. Primary branches vine-1 showed direct positive effect (0.018) via indirect positive effect of fruits vine-1 (0.032), sex ratio and fruit weight (0.023), days to last fruit harvest and fruit length (0.016), vine length (0.012) and days to 1st female flower initiation (0.010). Negative indirect effect was noticed with rest of the characters. The results also showed lower values for residual effect of 0.847 in path analysis study. The very low residual effect clearly demonstrated that most of the characters contributing towards fruit yield vine-1 in bitter gourd have been included. The other characters which were not included in the present study have very negligible contribution for green fruit yield vine-1.

4. Discussion

In bitter gourd, like other crops, the green fruit yield is controlled by several other quantitative traits, highly dependent on environmental factors including biotic and abiotic stresses. Therefore, selection on basis of phenotypic expression of a genotype may not be a sound proposition for selection in crop improvement programme. According to Robinsons (1966) [3] in general, the correlation studies are highly beneficial in selecting superior genotypes from their phenotypic expressions. Therefore, it is also essential to study the inter-relationship of those quantitative traits through correlation studies both at genotypic and phenotypic level for an effective selection.

The perusal of the present investigation showed that, between different character pairs both at genotypic and phenotypic level, were more or less in the same direction. However, the estimates of genotypic correlation were higher than that of phenotypic correlation, implying that the inherited association between these character pairs. The close association between genotypic and phenotypic correlation, as observed in the presented study, indicated that there was least influence of environmental factors in determining the association of these attributing traits with green fruit yield vine-1 in bitter gourd, probably due to a strong genetic makeup of the 22 segregants including their parents evaluated in the present investigation. This was in agreement with findings of Yadav *et al*. (2013) [7] in bitter gourd.

According to Verma and Singh (2015) [6], Jatav *et al*. (2016) [2] as well as Sidhu and Pathak (2016) [4], similar results on correlation of parameters like green fruits vine-1 (0.89 and 0.43) and days to last fruit harvest (0.46 and 0.26) were significant and positively correlated with fruit yield vine-1 in bitter gourd both at genotypic and phenotypic level, respectively. However, characters like vine length (0.25), number of nodes bearing 1st male flower (0.39), fruit weight (0.33) and primary branches vine-1 (0.92) was significantly positive with green fruit yield vine-1 only at genotypic level. None of the traits exhibited significant negative correlation with green fruit yield vine-1.It may be concluded that characters like sex ratio, number of node bearing 1st male flower, fruit weight, green fruits vine-1, days to last fruit harvest and primary branches vine-1 were important correlated characters contributing towards green fruit yield vine-1 in bitter gourd. Simultaneous improvement in above cited characters will be highly essential to develop desirable genotype (s) in bitter gourd improvement programme. Similar observations were laid out by Singh *et al*. (2012) [5] and Jatav *et al*. (2016) [2] in bitter gourd.

In general, yield is a very complex character controlled by many genes hence, influenced by various environmental factors. In nature, yield of any crop including bitter gourd is the resultant effect of many characters which are contributing directly or indirectly either alone or in combinations. Therefore, selection for a trait in one direction may otherwise influence another trait by direct or indirect effect via third variable. So, in a crop improvement programme, in order to obtain a desirable genotype, it is highly essential to study direct and indirect effects of various plant characters towards expression of green fruit yield vine-1.

In present investigation, the results on phenotypic path analysis of green fruit yield vine-1 of bitter gourd with other 12 important traits revealed that maximum direct effect on green fruit yield vine-1 was with green fruits vine-1 (0.311) closely followed by number of node bearing 1st male flower (0.297) than other traits. Other traits having positive direct effect with green fruit yield vine-1 in decreasing order were fruit weight (0.150), days to initiation of 1st female flower (0.149), days to last fruit harvest (0.109), primary branches vine-1 (0.108) and fruit girth (0.090). Similarly, negative direct path to green fruit yield vine-1 in bitter gourd were observed with traits like sex ratio (-0.032), days to 1st male flower initiation (-0.081), number of nodes bearing 1st female flower (-0.124), fruit length and vine length (-0.001). These results are in agreement with the findings of Gupta *et al*. (2015) [1] along with Sidhu and Pathak (2016) [4] in bitter gourd. The lower residual value of 0.847 in the present study revealed that most of the characters contributing towards green fruit yield vine-1 in bitter gourd has been included. The other characters which were not included in the present study has very negligible contribution for green fruit yield vine-1. Similar reports were suggested by Verma and Singh (2015) [6] in bitter gourd.

5. Conclusion

Direct selection will be effective for improvement of bitter gourd through traits like average fruit weight, fruits vine^{-1} and number of nodes bearing 1st male flower. Sex ratio, number of primary branches vine^{-1} and average fruit weight being positively and significantly correlated, hence, can be considered for further improvement in bitter gourd.

6. References

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