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Elucidation of correlation and path coefficient analysis for various morphological attributes in elite genotypes of bitter melon (*Momordica charantia* L.)

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Abstract

Bitter gourd or bitter melon is undoubtedly one of the most significant members of the cucurbitaceous vegetable crops. Through the exploitation of this highly potential crop, novel mechanisms and strategies can be developed that will open the wide arrays for further improvement. Keeping this objective in mind, a field investigation was conducted with twenty genotypes of bitter gourd at Vegetable Research Farm of Banaras Hindu University to estimate the character association as well as direct and indirect effects of different yield traits on average yield per plant through correlation and path coefficient analysis. The data demonstrated that the positive and significant interrelationship with average yield per plant was obtained by various traits, viz., node number of first staminate flower (0.375), node number of first pistillate flower (0.54), vine length (0.417), fruit length (0.356), fruit circumference (0.79), average fruit weight (0.768), fruits per plant (0.637), and internodal length (0.3) while negative significant correlation was followed by days to anthesis of first staminate flower (-0.331) and days to first harvest (-0.355). The average fruit weight (0.572) had highest direct positive effect on average yield per plant followed by traits like days to fifty per cent flowering (0.296), number of fruits per plant (0.274), and number of primary branches per plant (0.259) whereas maximum direct negative effect was recorded by days to anthesis of first staminate flower (-0.263) followed by internodal length (-0.162) and days to first harvest (-0.152). The traits with high positive direct effect should be more prioritised for effective selection of promising genotypes for further crop improvement programmes.

Keywords: Bitter gourd, path coefficient analysis, yield contributing traits

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Introduction

Cucurbits possess a distinctive place among different groups of vegetable crops. There are about 100 genera and 750 species almost equally divided between new and old world tropics in the family of Cucurbitaceae (Yamaguchi, 1983). Cucurbits can extensively be found in every part of India as well as in other tropical and sub-tropical parts of the world. It is grown extensively throughout India and other tropical and sub-tropical regions of the world. Among the cucurbits, *Momordica charantia* L. (Bitter gourd or bitter melon or balsam pear) is one of the major commercial crops in India which is suitable for hot and humid areas although it is well adapted to a wider range of climatic variations. It is basically a warm season, climbing annual of fast growing nature. In comparison with other cucurbits, bitter gourd has got a very high nutritive status due to its enrichment in various vitamins like retinol, thiamine, riboflavin, and ascorbic acid; and minerals like iron, calcium, potassium, phosphorous, etc. A range of pharmacological properties, viz., antidiabetic, antioxidant, antimicrobial, antiviral, antihepatotoxic, etc. have been credited to the crop (Behera et al. 2010). The understanding of correlation coefficient points out the interrelationship between two characters and forms a basis in the selection of the desirable plant type whereas is simply a standardized partial regression coefficient and measures the direct influence of one variable upon another and permits the partitioning of the correlation coefficient into components of direct and indirect effects. Path coefficient can be defined as "the ratio of the deviation when all causes are constant, except one in question, the variability of which kept in changed". In agriculture, plant breeders use the assistance of correlation and path coefficient analysis in order to ascertain the characters of high importance as selection criteria targeting to improve the crop yield

(Wright 1921; Dewey and Lu 1959). Path coefficient analysis provides a vivid idea about the contribution of individual independent parameter on the dependant one, i.e., yield. Although bitter gourd is an important member of cucurbitaceous vegetable group, adequate information is not readily available regarding these aspects. Hence, an investigation was carried out to estimate the character association among various quantitative as well as the direct and indirect effects of different independent characters on yield in elite genotypes of bitter gourd.

Materials and Methods

The investigation was planned and carried out at the Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University during kharif season of 2014. The experimental material consisted of twenty diverse genotypes of bitter gourd, viz., Jharli, Special Bolder Ucha, Meghna No. 2, Vikas, Improved Kathai, Arola-D, Dhanraj, NBR-Noble Katahi, Jaunpuri (Special), Preethi, PF Uchia, Karola Gor, G. Uchia, IC-085608, IC-085609, IC-085610, IC-085611, IC-085612, IC-085613, and IC-085615 collected from ICAR-Indian Institute of Vegetable Research, Varanasi (Uttar Pradesh) and Bidhan Chandra Krishi Viswavidyalaya, Mohanpur (West Bengal). The experiment was laid out in Randomized Complete Block Design (RCBD) in three replications and the unit plot size was 5 m^2 (2.5 m × 2 m). There is random allocation of the genotypes to a unit plot in each replication. To maintain a healthy crop stand, good cultural practices were precisely followed and plant protection measures were taken care of as per the requirement. The biometrical observations were recorded on five randomly selected plants excluding the border plants considering fourteen quantitative characters, viz., node number of first staminate flower, node number of first pistillate flower, days to anthesis of first staminate flower, days to anthesis of first pistillate flower, days to fifty per cent flowering, days to first harvest, number of primary branches per plant, vine length (m), internodal length (cm), fruit length (cm), fruit circumference (cm), average fruit weight (g), number of fruits per plant, and average yield per plant (kg). The data have been collected and subjected to correlation coefficient (Al-Jibouri et al. 1958) and path coefficient analysis according to the method suggested by Dewey and Lu (1959).

Results and Discussion

Correlation coefficient briefs about the relationship among various traits under study and path coefficient analysis gives an insight for partitioning of correlation coefficient into direct and indirect effects of different independent characters on the dependent one, i.e., yield. Path coefficient analysis delivers an effective method of revealing the direct and indirect causes of association and puts forth a critical analysis of the specific forces acting to generate a given correlation and estimates the relative relevance of each causal factor. The correlation coefficient and path coefficient analysis of different characters on genotypic basis in twenty diverse genotypes of bitter gourd are furnished in Table 2 and Table 3, respectively. The Analysis of variance for all the characters was found to be highly significant (Table 1) thus indicating wide variation among the twenty genotypes taken in the study.

Table 1: Analysis of variance for 14 quantitative characters in 20 bitter gourd genotypes

Character	Mean sum of square		
	Replications (df = 2)	Treatments (df = 19)	Error (df = 38)
Node number of first staminate flower	1.3705	19.850*	0.9431
Node number of first pistillate flower	1.1599	26.729*	2.2793
Days to anthesis of first staminate flower	1.2667	72.978*	3.933
Days to anthesis of first pistillate flower	0.8167	55.705*	4.0447
Days to fifty per cent flowering	11.4098	73.223*	7.2618
Days to first harvest	5.0544	87.080*	8.0219
Number of primary branches per plant	0.3086	5.480*	0.8262
Vine length (m)	0.0337	0.418*	0.0367
Internodal length (cm)	0.0389	0.973*	0.0570
Fruit length (cm)	5.5660	11.935*	1.9721
Fruit circumference (cm)	0.7674	11.209*	1.0539
Average fruit weight (g)	33.1271	406.399*	16.3435
Number of fruits per plant	2.8376	44.339*	5.7600
Average yield per plant (kg)	0.0019	0.1936*	0.0103

* Significant at p d" 0.05

The node number of first staminate flower showed significant and positive correlation with node number of first pistillate flower (0.770), fruit length (0.499), average fruit weight (0.476), vine length (0.342), and days to fifty per cent flowering (0.306); and demonstrated direct negative effect towards average yield per plant (-0.228) level while with respect to indirect effect, this trait exhibited highest positive effect towards average yield per plant via days to anthesis of first pistillate flower (0.009) and showed highest negative effect via node number of first pistillate flower (-0.181).

The node number of first pistillate flower was positively and significantly correlated with fruits per plant (0.667), average fruit weight (0.520), vine length (0.487), fruit circumference (0.386), days to fifty per cent flowering

(0.296), and fruit length (0.262). The trait exerted direct negative effect (-0.389) towards average yield per plant while considering the indirect effect, maximum positive indirect effect towards average yield per plant was recorded via number of primary branches per plant (0.049) and highest negative indirect effect was exerted via node number of first staminate flower (-0.309). Days to anthesis of first staminate flower showed positive and significant association with days to first harvest (0.980), days to anthesis of first pistillate flower (0.997), days to 50% flowering (0.910), number of primary branches per plant (0.416), fruit length (0.315) and internodal length (0.273). A direct positive effect (8.844) was recorded by the days to anthesis of first staminate flower towards average yield per plant. Regarding to indirect effect, this trait unveiled highest positive (8.818) and negative (-3.747) effect towards average yield per plant via days to anthesis of first pistillate flower and fruit circumference, respectively.

Days to anthesis of first pistillate flower recorded positive and significant correlation with days to 50% flowering (0.971), days to first harvest (0.774), number of primary branches per plant (0.281), and fruit length (0.255). A direct negative effect (-2.889) towards average yield per plant was recorded by days to anthesis of first pistillate flower. Regarding to indirect effect, highest positive indirect effect towards average yield per plant was exhibited via fruit circumference (0.95) and highest negative indirect effect was recorded via days to anthesis of first staminate flower (-2.88).

The days to fifty per cent flowering showed positive and significant correlation with days to first harvest (0.859), number of primary branches per plant (0.552) and fruit length (0.434); and demonstrated direct negative effect (-5.534) towards average yield per plant. Considering the indirect effect, this trait recorded highest positive indirect effect towards average yield per plant via fruit circumference (2.236) and maximum negative indirect effect via days to anthesis of first pistillate flower (-5.376).

The days to first harvest was positively and significantly correlated with number of primary branches per plant (0.392) and internodal length (0.254). The trait under study exhibited direct negative effect towards average yield per plant (-1.805). Regarding to indirect effect, highest positive indirect effect towards average yield per plant was demonstrated via fruits per plant (0.845) and highest negative indirect effect was shown via days to anthesis of first staminate flower (-1.77).

The number of primary branches per plant was positively and significantly correlated with internodal length (0.529), vine length (0.44), and fruit length (0.389); and had direct positive effect towards average yield per plant (2.336). Regarding to indirect effect, this trait exhibited highest positive effect towards average yield per plant via days to fifty per cent flowering (1.288) while highest negative effect was exhibited via fruit circumference (-1.069). Vine length was positively and significantly correlated with fruit length (0.353), fruits per plant (0.403), and average fruit weight (0.307). A direct negative effect (-2.948) was recorded by the vine length towards average yield per plant. With consideration of indirect effect, this trait revealed highest positive indirect effect towards average yield per plant

Table 2: Genotypic correlations among various yield and yield attributing traits in bitter gourd

Characters	NNFSA	NNFPA	DAFSF	DAFPF	DFPF	DFH	NPBP	VL	IL	FL	FC	AFW	FP	AYP
NNFSA	1.000	0.770*	0.004^{NS}	-0.037^{NS}	0.306*	0.067^{NS}	0.077^{NS}	0.342*	-0.341**	0.499**	0.123^{NS}	0.476**	0.145^{NS}	0.375**
NNFPA		1.000	0.016^{NS}	0.141^{NS}	0.296*	0.012^{NS}	-0.149^{NS}	0.487*	-0.707**	0.262*	0.386**	0.520**	0.667**	0.536**
DAFSF			1.000	0.997**	0.910*	0.980*	0.416*	-0.313*	0.273*	0.315*	-0.424**	-0.079^{NS}	-0.420**	-0.331**
DAFPF				1.000	0.971**	0.944**	0.380**	-0.184^{NS}	0.236^{NS}	0.356**	-0.329*	-0.044^{NS}	-0.256*	-0.237^{NS}
DFPF					1.000	0.859**	0.552**	-0.001^{NS}	0.166^{NS}	0.434**	-0.404**	0.036^{NS}	-0.227^{NS}	-0.097 ^{NS}
DFH						1.000	0.392**	-0.395**	0.254*	0.232^{NS}	-0.419**	-0.137^{NS}	-0.468**	-0.355**
NPBP							1.000	0.44*	0.529**	0.389**	-0.457**	-0.109^{NS}	-0.372**	-0.024 ^{NS}
VL								1.000	-0.115^{NS}	0.353**	0.085^{NS}	0.307*	0.403**	0.417**
IL									1.000	-0.041^{NS}	-0.785**	-0.636**	-0.629**	0.301**
FL										1.000	0.158^{NS}	0.662**	-0.127^{NS}	0.356**
FC											1.000	0.652**	0.631**	0.79**
AFW												1.000	0.216^{NS}	0.768**
FP													1.000	0.638**
AYP														1.000

Residual effect=0.0561; NS = Nonsignificant, ** = p d" 0.01, * = p d" 0.05

N.B., NNFSF=Node number of first staminate flower, NNFPF=Node number of first pistillate flower, DAFSF=Days to anthesis of first staminate flower, DAFPF=Days to anthesis of first pistillate flower, DFPF=Days to fifty per cent flowering, DFH=Days to first harvest, NPBP=Number of primary branches per plant, VL=Vine length (m), IL=Internodal length (cm), FL=Fruit length (cm), FC=Fruit circumference (cm), AFW=Average fruit weight (g), FP=Fruits per plant, and AYP=Average yield per plant.

Table 3: Direct (bold faced) and indirect effects of genotypic path coefficient for various traits on average fruit yield in bitter gourd

Characters	NNFSF	NNFPF	DAFSF	DAFPF	DFPF	DFH	NPBP	VL	IL	FL	FC	AFW	FP	Correlation with AYP
NNFSF	-0.228	-0.181	-0.001	0.009	-0.07	-0.015	-0.018	-0.078	-0.108	-0.114	-0.028	-0.109	-0.033	0.375**
NNFPF	-0.309	-0.389	-0.012	-0.053	-0.12	-0.006	0.049	-0.187	-0.122	-0.093	-0.138	-0.195	-0.248	0.536**
DAFSF	0.036	0.261	8.844	8.818	8.049	8.671	3.676	-2.769	-1.852	2.787	-3.747	-0.696	-3.71	-0.331**
DAFPF	0.107	-0.39	-2.88	-2.889	-2.806	-2.726	-1.098	0.532	0.307	-1.029	0.95	0.128	0.74	-0.237^{NS}
DFPF	-1.693	-1.706	-5.036	-5.376	-5.534	-4.755	-3.052	0.009	-0.819	-2.401	2.236	-0.199	1.257	-0.097^{NS}
DFH	-0.121	-0.026	-1.77	-1.704	-1.551	-1.805	-0.708	0.713	0.276	-0.42	0.757	0.247	0.845	-0.355**
NPBP	0.18	-0.294	0.971	0.888	1.288	0.916	2.336	1.027	0.894	0.909	-1.069	-0.255	-0.869	-0.024^{NS}
VL	-1.009	-1.416	0.923	0.543	0.005	1.165	-1.296	-2.947	-1.938	-1.041	-0.251	-0.906	-1.189	0.417**
IL	0.414	0.275	-0.183	-0.093	0.129	-0.133	0.334	0.573	0.872	0.383	-0.109	0.315	0.001	0.301**
FL	1.166	0.561	0.736	0.833	1.014	0.543	0.91	0.825	1.026	2.337	0.368	1.546	-0.297	0.356**
FC	-0.579	-1.668	1.995	1.549	1.903	1.974	2.154	-0.4	0.588	-0.742	-4.709	-3.072	-2.973	0.79**
AFW	0.8	0.842	-0.132	-0.075	0.06	-0.23	-0.184	0.517	0.607	1.113	1.097	1.681	0.364	0.768**
FP	0.852	3.751	-2.465	-1.505	-1.335	-2.751	-2.187	2.371	0.007	-0.746	3.71	1.272	5.877	0.638**

Residual effect=0.0614; NS = Nonsignificant, ** = p d" 0.01, * = p d" 0.05

N.B., NNFSF=Node number of first staminate flower, NNFPF=Node number of first pistillate flower, DAFSF=Days to anthesis of first staminate flower, DAFPF=Days to anthesis of first pistillate flower, DFPF=Days to fifty per cent flowering, DFH=Days to first harvest, NPBP=Number of primary branches per plant, VL=Vine length (m), IL=Internodal length (cm), FL=Fruit length (cm), FC=Fruit circumference (cm), AFW=Average fruit weight (g), FP=Fruits per plant, and AYP=Average yield per plant.

via days to fifty per cent flowering (1.288) and highest negative indirect effect via fruit circumference (-1.069).

Regarding direct effect, the internodal length had positive effect towards average yield per plant (0.872) whereas for indirect effect towards average yield per plant, maximum positive effect via vine length (0.573) and highest negative effect via days to anthesis of first staminate flower (-0.183) were recorded. Fruit length is positively and significantly correlated with average fruit weight (0.662) and towards average yield per plant, the fruit length (cm) exerted direct positive effect (2.337) while with respect to indirect effect, maximum positive indirect effect via average fruit weight (1.546) and highest negative indirect effect via fruits per plant (-0.297) were recorded towards average yield per plant.

Fruit circumference is positively and significantly correlated with average fruit weight (0.652) and fruits per plant (0.631); and showed direct negative (-4.709) effect towards average yield per plant. The trait unveiled highest positive indirect effect towards average yield per plant via number of primary branches per plant (2.154) and highest negative indirect effect via average fruit weight (-3.072). The average fruit weight had direct positive effect towards average yield per plant (1.681). The trait recorded highest positive indirect effect towards average yield per plant via fruit length (1.113) while maximum negative indirect effect was recorded via days to first harvest (-0.23). The number of fruits per plant demonstrated direct positive effect towards yield (5.877). This trait exhibited highest positive indirect effect towards average yield per plant via node number of first pistillate flower (3.751). Highest negative indirect effect via days to first harvest (-2.751) was recorded. These findings are in conformity with Singh et al. (2016), Kumari et al. (2018), Singh et al. (2014), Tyagi et al. (2018), Kumar et al. (2018), Yadav et al. (2013), Singh et al. (2015), and Janaranjani and Kanthaswamy (2015).

Critical investigation of results revealed that characters like node number of first staminate flower (0.375), node number of first pistillate flower (0.540), vine length (0.417), fruit length (0.356), fruit circumference (0.790), average fruit weight (0.768), fruits per plant (0.637), and internodal length (0.300) are positively and significantly correlated with yield while days to anthesis of first staminate flower (-0.331) and days to first harvest (-0.355) are negatively and significantly correlated with average yield per plant. The average fruit weight had maximum direct positive effect on average yield per plant followed by traits like days to fifty per cent flowering, number of fruits per plant, and number of primary branches per plant whereas highest direct negative effect was exhibited by days to anthesis of first staminate flower followed by internodal length and days to first harvest. These findings are in accordance with Sundaram (2010), Singh et al. (2012), Pandey et al. (2012), Dalamu and Behera (2013), and Rani et al. (2015). The traits with high positive direct effect should be given more emphasis as these can be used as effective selection criteria in order to advance the further crop improvement programme.

सारांश

करेला निसंदेह कद्दूवर्गीय सब्जियों में एक महत्वपूर्ण सब्जी है। इस फसल में उत्कृष्ट तंत्रों एवं रणनीतियों को अपनाकर भविष्य में और अधिक उन्नयन की गति को बढ़ाया जा सकता है। इस उद्देश्य को ध्यान में रखकर 20 प्रभेदों को सम्मिलित कर सब्जी अनुसंधान प्रक्षेत्र, कषि विज्ञान संस्थान, काशी हिन्दू विश्वविद्यालय में गुणों का संबंध तथा उपज व उपज घटकों के प्रत्यक्ष व अप्रत्यक्ष प्रभाव तथा पथ गुणांक विश्लेषण के लिए प्रक्षेत्र परीक्षण किया गया। आंकड़ों से स्पष्ट हुआ कि प्रति पौध औसत उपज के साथ अन्य गुणों जैसे प्रथम नर पुष्प विकास की गांठ संख्या (0.375), प्रथम मादा पुष्प विकास की गांठ संख्या (0.54), बेल की लंबाई (0.417), फल की लंबाई (0.356), फल की परिधि (0.79), फल की औसत (0.768), प्रति पौध फल संख्या (0.637) व पार्श्व गांठ की लम्बाई (0.3) का सकारात्मक और महत्वपूर्ण अन्तः संबंध प्राप्त हुआ जबकि प्रथम नर पुष्प का पुष्पन (–0.331) व प्रथम तुड़ाई के दिन (–0.355) के लिए नकारात्मक और महत्वपूर्ण सहसंबंध था। औसत फल भार (0.572) का प्रति पौध औसत उपज हेतु सबसे अधिक प्रत्यक्ष प्रभाव पाया गया और उसके बाद अन्य गुणों जैसे– 50 प्रतिशत पुष्पन के दिन (0.296), प्रति पौध फलों की संख्या (0.274) और प्रति पौध शाखाओं की संख्या (0.259) का रहा जबकि अधिकतम नकारात्मक प्रतयक्ष प्रभाव नर पुष्प के पुष्पन के दिन (–0.263) का था और इसके उपरान्त पार्श्व गांठ की लम्बाई (–0.162) व प्रथम तुड़ाई के दिन (–0.162) का रहा। उच्च सकारात्मक प्रत्यक्ष प्रभाव वाले गुणों की ज्यादा प्राथमिकता देना चाहिए जिसके माध्यम से उत्कष्ष्ट प्रभेदों का चयन किया जा सके और चयनित प्रभेदों को आगे फसल उन्नयन में उपयोग हो सके।

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