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Correlation and Path Coefficient Analysis in Bitter Gourd (*Momordica charantia* L.) Genotypes

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Correlation of various characters with yield is useful and provides criteria for direct selection of component characters. The other genetic parameter commonly used is the path analysis as given by Dewey and Lu, 1959. It critically breaks up different direct and indirect effects which finally add upto the correlation coefficient. The present investigation was undertaken at the Experimental field of Urban Technological Park Habbak, Srinagar, Jammu and Kashmir during *kharif*-2022. The experiment was laid out in Randomized Block Design with three replications and plant spacing of 2×1 m for thirty genotypes in order to study the association among yield and yield components, their direct and indirect influence on total marketable fruit yield. Observations were recorded on various

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growth and yield traits and seed traits. Positive and significant correlation was noted for fruit yield ha^{-1} with number of male flowers $plant^{-1}$, number of female flowers $plant^{-1}$, vine length (m), number of fruits, average fruit weight (g), leaf area (cm^2), number of seeds $fruit^{-1}$, seed weight $fruit^{-1}$ and fruit yield $plant^{-1}$ both at genotypic and phenotypic levels. Path coefficient analysis disclosed that traits such as number of fruits per plant, vine length (m), number of female flowers, average fruit weight(g) and number of seeds per fruit should be given due importance by selection for breeding of new cultivars as they exhibited the highest direct effects on the fruit yield ha^{-1}.

Keywords: Bitter gourd; correlation; path analysis.

1. INTRODUCTION

Botanically identified as "*Momordica charantia* L.", bitter gourd is a fairly well-known member of the herbaceous vine family "Cucurbitaceae". *Momordica* is a genus with around 45 species, most of which are found in Africa [1]. Bitter gourd is a quite popular "tropical and subtropical" commercially significant vegetable crop [2]. A range of pharmacological properties, viz., antidiabetic, antioxidant, antimicrobial, antiviral, antihepatotoxic, etc. have been attributed to the crop [3]. It's one of the most promising plants for managing diabetes and a useful food and medicinal plant for sustaining and enhancing human health. The bitter gourd is rich in a plethora of essential nutrients, including protein, calcium, magnesium, phosphorus, zinc, iron, carbohydrates, and ascorbic acid. The crop holds immense medicinal value due to the presence of a diverse range of bioactive compounds such as alkaloids, phytochemicals, especially antioxidants, vitamins, and minerals. These compounds have the ability to fight against cancer, diabetes, abdominal pain, kidney stones, fever as well as scabies [4]. The fruit is easy to digest, laxative, and said to have germicidal properties. It is thought to be beneficial for treating blood disorders, rheumatism, diabetes, asthma, and decreasing blood cholesterol. In addition, the fruits are utilized as a tonic, stimulant, thermogenic, vulnerary, stomachic carminative, purgative, anti-helminthic, and anti-inflammatory. A decoction prepared from the root extract can help with queasiness, hemorrhoids, and miscarriages [5]. The fruit's hypoglycemic ingredient, "*Charantin*," has been established through extensive and thorough investigation into its antidiabetic qualities. The bitter gourd fruit contains the following nutrients per 100g of edible portion: 95g water, 17 Kcal energy, 1g protein, 0.17g fat, 2.8g total dietary fiber, 19 mg Ca, 0.43 mg Fe, 17 mg Mg, 84 mg total ascorbic acid, 0.04 mg thiamine, 0.04 mg riboflavin, 0.4 mg niacin, and 24 mg Vitamin A. In India, the bitter gourd crop covers 101,000 hectares and produces 1174 thousand metric tonnes of fresh yield annually [6]. The leading bitter gourd producing states are Maharashtra, Uttar Pradesh, Gujarat, Rajasthan, Punjab, Tamil Nadu, Karnataka, Kerala, Andhra Pradesh, West Bengal, Odisha, Assam and Bihar. In Kashmir, this crop is cultivated on a marginal scale and as a result, precise data on area and production is unavailable.

A systematic breeding programme is needed to improve the yield potential and other horticultural qualities of bitter gourd, an important vegetable crop. Yield is a highly complex character which is highly influenced by environment, hence selection based on yield alone may limit the improvement, whereas yield component characters are less complex in inheritance and influenced by the environment to a lesser extent. Thus, effective improvement in yield may be brought about through selection of various yield component characters, which show association among themselves and also with yield. Plant breeder needs to obtain the simple correlations as well as the extent of direct and indirect effects of attributes on yield that could be useful to predict superior cross combinations and to identify traits for ideal plant type and aid in indirect selection. In the present study phenotypic and genotypic correlations were employed to determine direct and indirect effects of yield and yield contributing characters in selection of superior cross combinations in bitter gourd genotypes. Path coefficient provides a better index for selection than mere correlation coefficient by partitioning the correlation coefficients between yield and its components into direct and indirect effects. The information on such aspects can be of great help in formulating an appropriate breeding strategy for genetic upgradation of this crop.

2. MATERIALS AND METHODS

The present research study was carried out at the experimental field of Urban Technological

Park, Habbak, Srinagar, Jammu and Kashmir during *kharif*-2022. It is situated at an altitude of 1608 meters above mean sea level lying between 34.16º North latitude and 74.83º East longitude. The climate is temperate characterized by mild summers. January and June are the months with the lowest and highest recorded mean temperatures, respectively. The months of March-April witness the highest amount of rainfall. The experimental material consisted of thirty genotypes of bitter gourd which were obtained from various sources. The genotypes' seeds were sown in the field for the comparative assessment of several quantitative and quality traits. The field experiment was laid out using Randomized Block Design comprising of thirty treatments and three replications. The customary cultural methods for producing a high-quality crop were adhered to. Weeds and insect pests were always kept out of the field. Observations were recorded on seventeen quantitative traits viz. days to appearance of 1st male flower, days to appearance of 1st female flower, number of male flowers plant^{-1}, node at which 1st female flower appears, number of female flowers plant^{-1}, vine length (m), fruit length (cm), fruit diameter (cm), number of fruits plant^{-1}, average fruit weight (g), leaf area (cm^2), 100 seed weight (g), number of seeds fruit^{-1}, seed weight fruit^{-1} (g), days to 1st fruit harvest, fruit yield plant^{-1} (kg), fruit yield hectare^{-1} (q).The observations on different parameters were taken from three randomly selected plants from each line of all replications.

Estimates of genotypic and phenotypic variances and covariances were substituted in the formula suggested by Panse and Sukatme [7]. so as to calculate the correlation coefficients between all possible pairs of characters. The methodology suggested by Wright [8] and Li [9]. was adopted while using the formula given by Dewey and Lu [10]. to carry out path coefficient analysis. All the above computations were carried out using the R software at the Division of Agricultural statistics, SKUAST-Kashmir, Shalimar.

3. RESULTS AND DISCUSSION

In the present study, the correlation coefficients were computed and path analysis carried out among thirty different genotypes of bitter gourd. In order to make indirect selection for the enhancement of economic traits, knowledge of the association between various attributes and economic traits is required. Studies of correlation help us in understanding the relationships that exist between highly heritable traits and the economic traits and how each trait contributes to the genetic make-up of a crop. Genotypic correlations provide an estimate of inherent association between genes controlling any two characters. Hence, it is of greater significance and could be effectively utilized in formulating an effective selection scheme. Perusal (Table 1) indicated that in the present investigation, the magnitude of the genotypic correlation coefficients was higher than the phenotypic coefficients, establishing the predominance of heritable components and demonstrating the additive nature of gene action for these traits. Similar results were derived from the studies of Rani et al. [11], Prasad et al. [12] and Prasanth et al [13].

Correlation coefficients disclosed that the economically important trait, i.e. fruit yield hectare^{-1} was found to have a positive and significant correlation with the traits; number of male flowers plant^{-1} (r_g = 0.391, r_p = 0.392), number of female flowers plant^{-1} (r_g = 0.883, r_p = 0.878), [14]. vine length (r_g = 0.93, r_p = 0.913) [11]. number of fruits plant^{-1} (r_g = 0.919, r_p = 0.916) [15]. average fruit weight (r_g = 0.493, r_p = 0.459) [16]. leaf area (r_g = 0.518, r_p = 0.51), number of seeds fruit^{-1} (r_g = 0.591, r_p = 0.587), seed weight fruit^{-1} (r_g = 0.429, r_p = 0.419) and fruit yield plant^{-1} (r_g = 0.997, r_p = 0.973) both at genotypic and phenotypic levels. A positive and significant phenotypic correlation of this trait with fruit length (r_p = 0.295) and fruit diameter (r_p = 0.294) was also observed. Similar results were observed by Prasad et al [12]. Prasanth et al [13]. and Reddy et al [17]. Also, the traits days to appearance of 1st male flower (r_g = -0.71, r_p = -0.693), days to appearance of 1st female flower (r_g = -0.435, r_p =- 0.42), node number at which 1st female flower appeared (r_g = -0.361, r_p = -0.39) and days to 1st fruit harvest (r_g = -0.396, r_p =-0.39) exhibited negative and significant genotypic as well as phenotypic correlation with fruit yield hectare^{-1}. These findings were similar to those reported by Yadav et al [18]. Singh et al [19]. and Prasad et al [12]. These mentioned traits may be given primary importance during the course of selection to enhance the yield of bitter gourd.

Correlation analysis indicates the association pattern of component traits with yield, it simply represents the overall association of a particular trait with yield rather than providing cause and effect relationship. The technique of path coefficient analysis developed by Wright [8]. and demonstrated by Dewey and Lu [10]. facilitates in partitioning the correlation coefficients into direct

Table 1. Estimates of genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients among different growth and yield attributing characters in Bitter gourd *(Momordica charantia L.)*

Parameters	DFMF	DFFF	NOMF	NFFF	NOFF	VL	FL	FD	NOF	AFW	LA	100 SW	NSPF	SWPF	DFFH	FYPP	FYPH
DFMF	**1.00**	0.662**	-0.58**	-0.1299	-0.65**	-0.69**	-0.374*	0.1742	-0.70**	-0.1617	-0.389*	-0.2721	-0.2398	-0.3266	0.578**	-0.68**	-0.71**
DFFF	0.647**	**1.00**	-0.51**	0.0438	-0.54**	-0.54**	-0.0549	0.2227	-0.57**	0.2147	-0.1243	-0.1066	-0.2963	-0.3212	0.791**	-0.41*	-0.435*
NOMF	-0.577**	-0.51**	**1.00**	-0.0124	0.927**	0.77**	-0.112	0.1287	0.911**	-0.0241	0.3242	0.1401	0.505**	0.3424	-0.462*	0.3742*	0.3911*
NFFF	-0.1302	0.0535	-0.0123	**1.00**	-0.0629	-0.1174	0.0035	-0.1602	-0.0382	0.1029	-0.0735	0.137	-0.0721	-0.1119	0.0069	-0.354*	-0.361*
NOFF	-0.643**	-0.54**	0.922**	-0.0571	**1.00**	0.91**	0.0409	0.139	0.983**	0.0587	0.431*	0.1146	0.576**	0.3941*	-0.49**	0.898**	0.883**
VL	-0.686**	-0.52**	0.759**	-0.122	0.887**	**1.00**	0.197	0.177	0.935**	0.2186	0.54**	0.0312	0.5243**	0.2804	-0.52**	0.936**	0.93**
FL	-0.364**	-0.0621	-0.1103	0.0209	0.0458	0.1807	**1.00**	-0.2168	0.1107	0.580**	0.1334	0.3196	0.1393	0.3907*	0.0575	0.2904	0.3011
FD	0.1559	0.2351*	0.1197	-0.1732	0.1148	0.1684	-0.2209*	**1.00**	0.1556	0.459**	0.2711	-0.2485	0.3992*	0.0267	0.1196	0.3491	0.3266
NOF	-0.701**	-0.56**	0.907**	-0.0374	0.975**	0.917**	0.1111	0.1342	**1.00**	0.1144	0.46*	0.1193	0.587**	0.4074	-0.52**	0.929**	0.919**
AFW	-0.1594	0.2111*	-0.0237	0.1045	0.0594	0.2129*	0.571**	0.424**	0.1144	**1.00**	0.2829	0.0531	0.224	0.2654	0.2355	0.4578*	0.493*
LA	-0.386**	-0.1237	0.323**	-0.0711	0.429**	0.533**	0.1313	0.2479*	0.459**	0.282**	**1.00**	-0.0605	0.3108	0.0822	-0.1944	0.52**	0.518**
100 SW	-0.2694*	-0.1031	0.1394	0.1321	0.1117	0.036	0.306**	-0.2317*	0.1161	0.052	-0.0598	**1.00**	0.1265	0.643**	0.1386	0.1946	0.1985
NSPF	-0.233*	-0.29**	0.499**	-0.0521	0.572**	0.499**	0.1443	0.3436**	0.579**	0.2237*	0.30**	0.1212	**1.00**	0.707**	-0.1692	0.615**	0.591**
SWPF	-0.324**	-0.30**	0.336**	-0.1214	0.379**	0.285**	0.366**	0.0513	0.396**	0.256*	0.079	0.634**	0.673**	**1.00**	-0.0376	0.4216*	0.4293*
DFFH	0.568**	0.772**	-0.45**	0.0161	-0.48**	-0.51**	0.0584	0.1012	-0.52**	0.235*	-0.1926	0.1383	-0.159	-0.0417	**1.00**	-0.371*	-0.396*
FYPP	-0.662**	-0.39**	0.3841*	-0.384*	0.874**	0.898**	0.279**	0.315**	0.901**	0.447**	0.50**	0.1871	0.5972**	0.405**	-0.35**	**1.00**	0.997**
FYPH	-0.693**	-0.42**	0.3922*	-0.35*	0.878**	0.913**	0.295**	0.294**	0.916**	0.459**	0.51**	0.197	0.587**	0.419**	-0.39**	0.973**	**1.00**

*, **= Significant at 5% and 1% respectively

DFMF: Days to appearance of 1st male flower; NFFF: Node number at which 1st female flower appears; FL: Fruit length (cm); AFW: Average fruit weight (g); NSPF: Number of seeds fruit^{-1}; FYPP: Fruit yield plant^{-1} (kg)

DFFF: Days to appearance of 1st female flower; NOF: Number of female flowers plant^{-1}; FD: Fruit diameter (cm); LA: Leaf area (cm^2); SWPF: Seed weight fruit^{-1} (g); FYPH: Fruit yield hectare^{-1} (q)

NOMF: Number of male flowers plant-^{1}; VL: Vine length (m); NOF: Number of fruits plant^{-1}; 100SW: 100 seed weight(g); DFFH: Days to 1st fruit harvest

Table 2. Path matrix showing direct (diagonal) and indirect (off-diagonal) effects of different growth and yield attributing characters on fruit yield of Bitter gourd (*Momordica charantia* L.)

Parameters	DFMF	DFFF	NOMF	NFFF	NOFF	VL	FL	FD	NOF	AFW	LA	100 SW	NSPF	SWPF	DFFH	Corr. Q
DFMF	**-0.2539**	-0.1018	0.0895	0.0200	0.1005	0.1074	0.0575	-0.0268	0.1090	0.0249	0.0599	0.0419	0.0369	0.0503	-0.0890	-0.71**
DFFF	-0.0180	**-0.1271**	0.0140	0.0012	0.0149	0.0147	0.0015	-0.0060	0.0156	-0.0058	0.0034	0.0029	0.0080	0.0087	-0.0215	-0.435*
NOMF	0.2023	0.1800	**0.3476**	0.0043	-0.3226	-0.2677	0.0389	-0.0447	-0.3169	0.0084	-0.1127	-0.0487	-0.1755	-0.1190	0.1609	0.3911*
NFFF	0.0139	0.0047	0.0013	**-0.1068**	0.0067	0.0125	-0.0004	0.0171	0.0041	-0.0110	0.0079	-0.0146	0.0077	0.0120	-0.0007	-0.361*
NOFF	-0.1047	-0.0880	0.1478	-0.0101	**0.5603**	0.1459	0.0065	0.0223	0.1577	0.0094	0.0691	0.0184	0.0924	0.0632	-0.0794	0.883**
VL	0.0769	0.0596	-0.0848	0.0129	-0.1003	**0.7102**	-0.0217	-0.0195	-0.1031	-0.0241	-0.0599	-0.0034	-0.0578	-0.0309	0.0575	0.93**
FL	0.0564	0.0083	0.0169	-0.0005	-0.0062	-0.0297	**0.1509**	0.0327	-0.0167	-0.0876	-0.0201	-0.0482	-0.0210	-0.0590	-0.0087	0.3011
FD	-0.0106	-0.0135	-0.0078	0.0097	-0.0084	-0.0108	0.0132	**0.1608**	-0.0095	-0.0279	-0.0165	0.0151	-0.0243	-0.0016	-0.0073	0.3266
NOF	-0.7331	-0.5956	0.9433	-0.0395	0.7780	0.9679	0.1146	0.1610	**0.8504**	0.1184	0.4761	0.1234	0.6074	0.4215	-0.5462	0.919**
AFW	-0.0783	0.1040	-0.0117	0.0498	0.0284	0.1059	0.2814	0.2227	0.0554	**0.4844**	0.1370	0.0257	0.1085	0.1285	0.1141	0.493*
LA	0.0208	0.0066	-0.0173	0.0039	-0.0230	-0.0290	-0.0071	-0.0145	-0.0246	-0.0151	**0.3534**	0.0032	-0.0166	-0.0044	0.0104	0.518**
100 SW	-0.0317	-0.0124	0.0163	0.0160	0.0134	0.0036	0.0373	-0.0290	0.0139	0.0062	-0.0071	**0.1167**	0.0148	0.0751	0.0162	0.198
NSPF	-0.0458	-0.0567	0.0965	-0.0138	0.1102	0.1002	0.0266	0.0763	0.1122	0.0428	0.0594	0.0242	**0.3912**	0.1353	-0.0323	0.591**
SWPF	0.0816	0.0802	-0.0855	0.0279	-0.0984	-0.0700	-0.0975	-0.0067	-0.1017	-0.0663	-0.0205	-0.1608	-0.1767	**0.2497**	0.0094	0.4293*
DFFH	0.0118	0.0161	-0.0094	0.0001	-0.0101	-0.0106	0.0012	0.0024	-0.0108	0.0048	-0.0040	0.0028	-0.0034	-0.0008	**-0.1204**	-0.396*

RESIDUAL EFFECT= 0.1023

DFMF: Days to appearance of 1st male flower; NFFF: Node number at which 1st female flower appears; FL: Fruit length (cm); AFW: Average fruit weight (g); NSPF: Number of seeds fruit^{-1}; FYPP: Fruit yield plant^{-1} (kg)

DFFF: Days to appearance of 1st female flower; NOF: Number of female flowers plant^{-1}; FD: Fruit diameter (cm); LA: Leaf area (cm^2); SWPF: Seed weight fruit^{-1} (g); FYPH: Fruit yield hectare^{-1} (q)

NOMF: Number of male flowers plant-^{1}; VL: Vine length (m); NOF: Number of fruits plant^{-1}; 100SW: 100 seed weight(g); DFFH: Days to 1st fruit harvest and indirect contribution of various traits on yield. As such, it measures the direct influence of one variable upon other. Such information would be of great value in enabling the breeder to specifically identify important component traits of yield and utilize the genetic stock for improvement in a planned way. Path coefficient can be simply defined as a standardized partial regression coefficient which in addition to measuring the direct effect of one variable on the other splits the correlation coefficients into measures of direct and indirect effects. Path coefficient analysis depicts the effects of different independent characters individually and in combination with other character on fruit yield. The data on path coefficient analysis at genotypic level showing direct and indirect effects of significant characters over total marketable fruit yield per hectare is tabulated in Table 2.

In the present study the path coefficient analysis (Table 2) disclosed that the highest direct positive effect on fruit yield ha^{-1} was exerted by number of fruits $plant^{-1}$ (0.8504) [15]. followed by vine length (0.7102) [17]. number of female flowers $plant^{-1}$ (0.5603), average fruit weight (0.4844) [16]. and number of seeds $fruit^{-1}$ (0.3912). The genotypic correlation coefficients of these characters with fruit yield ha^{-1} were equal to 0.919, 0.93, 0.883, 0.493 and 0.591 respectively indicating that direct selection of these traits will be effective in developing bitter gourd cultivars with improved yield potential. Similar results were observed by Singh et al [19]. Yadagiri et al [14]. and Triveni et al [20]. The direct effects of component traits like days to appearance of 1st male flower (-0.2539), days to appearance of 1st female flower (-0.1271), node number at which 1st female flower appeared (-0.1068) and days to 1st fruit harvest (-1204) were negative. Therefore, these traits should be considered of little importance in the selection programme of Bitter gourd. These results are in agreement with those reported by Islam et al [21]. Singh et al [19]. Prasanth et al [13]. and Tiwari et al [22].

The residual effect value in the current study was 0.1023, indicating that the characters selected for the study are the primary contributors to yield and that the characters selected for the current study account for the variability in yield. Similarly, Mahesh et al [23]. Prasanth et al [13]. and Reddy et al [17]. observed very few residual effects while working on the similar traits in bitter gourd.

4. CONCLUSION

It is clear from the above discussion that tremendous potential exists for converging the elite allelic resources present in these bitter gourd genotypes through a systematic breeding and selection approach so as to recover high yielding recombinants, with good quality characteristics. The correlation coefficients obtained disclosed that the economically significant trait i.e., fruit yield $hectare^{-1}$ (q) exhibited significant and positive association with number of male flowers $plant^{-1}$, number of female flowers $plant^{-1}$, vine length (m), fruit length (cm), fruit diameter (cm), number of fruits, average fruit weight (g), leaf area (cm^2), number of seeds $fruit^{-1}$, seed weight $fruit^{-1}$ and fruit yield $plant^{-1}$ both at genotypic and phenotypic levels. On the other hand, days to appearance of 1st male flower, days to appearance of 1st female flower, node number at which 1st female flower appeared and days to 1st fruit harvest showed negative and significant association with fruit yield ha^{-1} (q). According to the path coefficient analysis, the traits having highest positive direct effect on fruit yield ha^{-1} (q) were observed to be number of fruits per plant followed by vine length (m), number of female flowers, average fruit weight(g) and number of seeds per fruit. These characteristics could thus be employed as direct selection criteria for breeding of high yielding bitter gourd genotypes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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