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Correlation and Path Coefficient Analysis in Chilli (*Capsicum annuum* L.) Based on Yield and Yield Related Traits

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ABSTRACT

An experiment was carried out in the field laboratory of the Department of Genetics and Plant Breeding of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during the period from October 2018 to April 2019. The experiment was set up in a randomized complete block design (RCBD) and three replications were used. The aim of the study was to assess the character association and direct and indirect effect of independent characters on green yield of 28 chilli genotypes. A comparison between genotypic and phenotypic correlation coefficients revealed that the former was higher. At both the genotypic and phenotypic levels, correlation coefficients revealed that fruit yield per plant was significantly and positively linked with fruit length, fruit diameter, individual fruit weight, number of seeds per fruit, and plant height. Individual fruit weight had the most significant positive direct impact on fruit yield, followed by the number of fruits per plant, fruit diameter, and fruit length. Therefore, these characteristics could be regarded as critical selection criteria for the enhancement of chilli yield.

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INTRODUCTION

Chilli (*Capsicum annuum* L.), originally from South and Central America and belonging to the Solanaceae family, is widely cultivated globally both as a vegetable and a spice crop (Dias et al., 2013; Wahyuni et al., 2012). Known by various names such as red pepper, bell pepper, pod pepper, hot pepper, chilli pepper, paprika, pimento, and capsicum in different regions, it holds significant agricultural importance. In 2020, China alone produced 46 percent of the world's total of 36 million tons of green chilli peppers (FAOSTAT, 2022). With over 4000 varieties worldwide, chillies vary widely in taste, size, shape, color, and culinary uses. Commonly valued for their pungent flavor, chillies are consumed globally in fresh, dried, or powdered forms (El-Ghorab et al., 2013). The components of chilli contribute significantly to its nutritional value, aroma, texture, and color, while also serving as a valuable source of oleoresin utilized in the food and beverage industries, as well as in medicine (Marín et al., 2004; Osuna-García et al., 1998). It is rich in proteins, lipids, carbohydrates, fibers, and minerals such as calcium, phosphorus, and iron, along with vitamins A, D, E, C, K, B2, and B12 (El-Ghorab et al., 2013). Chilli is primarily a self-pollinated crop, though varying degrees of outcrossing, ranging from 2% to 96%, have been observed under open pollination conditions (AVRDC, 2001).
Chilli cultivation is widespread throughout the year in Bangladesh, benefiting from the country's diverse geo-climatic regions that foster a rich diversity of chilli varieties. Improvements in chilli crops have been achieved by exploiting existing sources of variability, given the high genetic diversity observed naturally in most yield attributes (Rahman et al., 2024). The exchange of chilli germplasm and extensive introgression of traits among local cultivars have contributed to increased variability and the emergence of new genetic combinations. As yield is a complex trait influenced by numerous component traits, understanding the interrelationships between these traits is crucial for developing optimal selection indices to enhance yield (Saisupriya et al., 2020). Wright (1921) introduced the concept of correlation and path analysis, pioneering the systematic examination of relationships between predictor and response variables. Genotypic correlations focus on genetic associations between different characters, while phenotypic correlations reflect observable traits and their interdependencies. These analyses provide insights into the strength and nature of associations among various traits, offering valuable information for understanding genetic and environmental influences on plant characteristics. Path analysis is commonly used to explore cause-and-effect relationships among different traits affecting yield (Dewey and Lu, 1959). This technique breaks down direct and indirect effects, revealing how various traits contribute to overall yield performance. By identifying independent variables that exert significant positive effects, breeders can strategically enhance yield through targeted selection in breeding programs.

In this study, the genotypic and phenotypic paths influencing yield per plant were analyzed by selecting the most influential independent variables. This analysis aimed to determine how specific genetic and observable traits contribute to the overall yield of each plant. By identifying and evaluating these influential factors, researchers can better understand the complex interactions and pathways that impact the productivity of chilli plants. This approach helps in developing targeted strategies for improving yield through breeding and management practices. Therefore, in order to evaluate the chilli germplasm and investigate the character associations as well as the direct and indirect effects of independent characters on dependent traits (fruit yield/plant), a field investigation was conducted.

MATERIALS AND METHODS

Study site

The research was conducted from October 2018 to April 2019 in the field laboratory of the Department of Genetics and Plant Breeding at Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur. The experimental site was situated in the centre of the Madhupur Tract, agro-ecological zone (Madhupur Tract, AEZ - 28), at an elevation of 8.4 metres above sea level and 24.05° N latitude and 90.25° E longitude. The soil in the experimental field had a clay loam texture and a pH of 5.5. The subtropical climate at the experimental site is marked by high rainfall from June to September, along with a steady drop in temperature starting in September. Figure 1 contains the meteorological data for the study period.

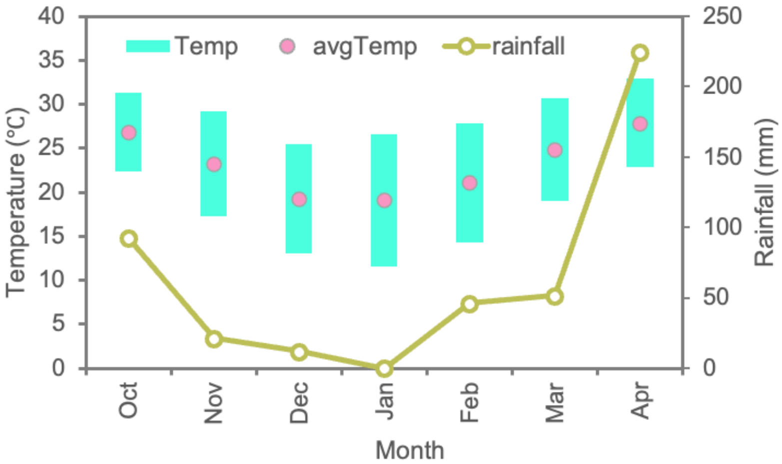

Figure 1. Weather condition of the study location. The upper and lower limit of the ribbon designate the maximum and minimum temperature, respectively, whereas the red point indicates the average temperature. The line designates average rainfall.

Field experiment

The field underwent meticulous preparation through the process of ploughing and cross-plowing, which was repeated three to four times, followed by laddering. Fertilizers applied in the plots were urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum, zinc sulphate, and boric acid @ 270–170-100–150–115–88 kg/ha, respectively. During final land preparation, the total amount of all fertilizers, except urea, was applied at the time of land preparation. At the same time, 10 t/ha of cow dung was also applied. The total dose of urea was split into two installment and they were applied at 15 and 60 days after transplanting.

The design of the experiment was a Randomised Complete Block Design (RCBD) with three replications. The experimental area was separated into three blocks. Each block was assigned twenty-eight different chilli genotypes at random. The distance between rows and plants remained at 45 cm. A one-meter spacing was maintained between the replication blocks. A population of twenty plants was maintained per replication per genotype by planting one plant per hill. The area between two blocks was converted into a drain with a depth of about 20 cm to facilitate irrigation and rapid water drainage. The seedlings were transplanted on December 28, 2018. Raised beds were ready for transplanting. One seedling was transplanted per pit and light irrigation was given immediately after transplanting. Gap filling was carried out after a week, whenever previously transplanted seedlings died. The other suggested procedures were followed in order to cultivate healthy chilli crop.

During the crop cycle, appropriate intercultural operations were carried out to ensure healthy plant growth and development, such as crop irrigation during the vegetative and reproductive stages, weeding, and soil mulching when needed. The first and second weeding were performed 15 and 30 days after transplanting (DAT), respectively, followed by a top dressing with urea. Bamboo stalks were used for supporting the whole bearing plants. Irrigation was given at regular intervals. The recommended amount of urea was given in three installments: 15, 30, and 50 days after transplantation (DAT). During the experimental period, a variety of insect pests were used, including thrips, aphids, and mites. After 10 days of transplanting to 1 month before harvesting at 3-day intervals, Tiddo 20 SL @2.5 mL/10L and Vertimec 18 EC @ 1.2 mL/L were sprayed to prevent mites and thrips attack, respectively. The plants were also drenched with Regent powder @ 10 mL/L to control the incidence of severe thrips attack.

Data Collection

Five plants were chosen at random from each genotype, and the selected plants were labeled for data collection on yield and yield-related characteristics. Days to first flowering, fifty percent flowering, hundred percent flowering, first fruit setting, fifty percent fruit setting, hundred percent fruit setting, first green fruit maturity, fifty percent green fruit maturity, and hundred percent green fruit maturity were all recorded prior to fruit harvesting. Fruit length, diameter, number of fruits per plant, individual fruit weight, number of seeds per fruit, and fruit production per plant were all measured after harvesting. Green fruits were collected when they were fairly firm and crunchy. Fruits were harvested three times per replicate. Plant height was measured during the last harvest.

Data analysis and visualization

The variance and covariance components were used to calculate both genotypic and phenotypic correlation coefficients between two characters, as suggested by Al-Jibouri et al. (1958). Path coefficient analysis was performed utilizing phenotypic correlation values of yield-related factors, as proposed by Wright (1921) and demonstrated by Dewey and Lu (1959). 'R' (version 4.02), (R Core Team, 2021) an open-source statistical language, was used for all analyses.

RESULTS AND DISCUSSION

Correlation co-efficient analysis

The results of the estimation of the phenotypic (P) and genotypic correlation (G) coefficients for ten characters are summarized in Table 1. Generally, it was noted that genotypic correlation coefficients were greater than phenotypic correlation coefficients. This could be interpreted as a strong inherent genotypic relationship between the traits studied, but their phenotypic expression was impeded by the influence of environmental factors (Saisupriya et al., 2020). Fruit yield per plant was significantly and positively correlated with fruit length (G: 0.424, P: 0.402), fruit diameter (G: 0.496, P: 0.368), individual fruit weight (G: 0.921, P: 0.879), number of seeds per fruit (G: 0.706, P: 0.590) and plant height (G: 0.488, P: 0.459) at both genotypic and phenotypic levels (Table 1). However, fruit yield had significant positive correlation with days to 50% flowering only at genotypic level (G: 0.607) and with number of fruits per plant only at phenotypic level (P: 0.444). Plant height had fair positive correlation with number of fruits per plant (G: 0.640, P: 0.522) and moderate positive correlation with days to 50% fruit setting (G: 0.436, P: 0.401) and days to 50% green fruit maturity (G: 0.380, P: 0.344) at both genotypic and phenotypic levels. Individual fruit weight was found to have strong positive correlation with number of seeds per fruit (G: 0.761, P: 0.629), fair positive correlation with days to 50% flowering (G: 0.608) at genotypic level, and with fruit diameter (G: 0.682, P: 0.563) at both levels. It had moderate positive correlation with fruit length (G: 0.453, P: 0.444) at both levels. Number of seeds per fruit was positively correlated with fruit diameter (G: 0.618, P: 0.485). Days to 50% fruit setting positive affected number of fruits per plant (G: 0.517, P: 0.440) both at genotypic and phenotypic levels. Fruit diameter was positively correlated days to 50% flowering (G: 0.386) only at genotypic level. Days to 50% flowering, 50% fruit setting and 50% green fruit maturity had fair to strong positive correlations at both levels. There were some negative correlations among the parameters, however, none of them were significant. Bijalwan and Mishra (2016), Gupta et al. (2009), Ullah et al. (2011), Chattopadhyay et al. (2011), Kumar et al. (2012) and Yatung et al. (2015) also reported similar findings for green fruit weight, fruit yield per plant, length of fruit and branching capacity. Other researchers (Bijalwan and Mishra, 2016; Dahiya et al., 1991; Nandpuri et al., 1970) have also reported a negative and significant correlation between fruit yield per plant and the number of days to 50% flowering at both the genotypic and phenotypic levels.

Table 1. Genotypic and phenotypic correlation co-efficient for yield and yield related characters of 28 chilli genotypes

		DFTF	**DFTS**	**DFTM**	**FRLN**	**FRDM**	**FRPP**	**IFRW**	**NSPF**	**FYPP**
DFTS	G	1.139**								
	P	0.334**								
DFTM	G	1.179**	0.851**							
	P	0.323**	0.788**							
FRLN	G	0.198	-0.154	-0.138						
	P	0.050	-0.136	-0.135						
FRDM	G	0.386*	-0.033	0.113	0.054					
	P	0.089	-0.026	0.078	0.060					
FRPP	G	0.163	0.517**	0.316	-0.026	-0.208				
	P	0.023	0.440**	0.259*	-0.021	-0.192				
IFRW	G	0.608**	0.111	0.205	0.453*	0.682**	0.070			
	P	0.181	0.098	0.199	0.444**	0.563**	0.065			
NSPF	G	0.273	-0.161	-0.106	0.354	0.618**	0.053	0.761**		
	P	0.095	-0.119	-0.085	0.276*	0.485**	0.110	0.629**		
FYPP	G	0.607**	0.171	0.189	0.424*	0.496**	0.359	0.921**	0.706**	
	P	0.158	0.163	0.170	0.402**	0.368**	0.444**	0.879**	0.590**	
PLHT	G	0.147	0.436*	0.380*	0.168	-0.155	0.640**	0.287	0.087	0.488**
	P	0.068	0.401**	0.344**	0.169	-0.094	0.552**	0.261*	0.113	0.459**

DFTS, DFTS and DFTM designate days to 50% flowering, 50% fruiting, and 50% green fruit maturity, respectively; FRLN and FRDM implies fruit length (cm), and fruit diameter (mm), respectively; FRPP designates number of fruits/plants, whereas IFRW is individual fruit weight (g), and NSPF is numbers of seeds/fruit; FYPP: fruit yield/plant (kg), PLHT: plant height (cm)

Path coefficient analysis

The exact relationship between yield and yield attributes may not be provided by the simple correlation coefficient, as the mutual relationship of component characters may vary in both magnitude and direction (Deepo et al., 2020). Consequently, it is imperative to perform path coefficient analysis, which enables a critical evaluation of the specific direct and indirect effects of characters and quantifies their relative intensity in determining the ultimate objective yield. The dependent variable was the produce yield per plant, and path analysis was conducted at the phenotypic and genotypic levels. Table 2 presents the estimates of the direct and indirect effects of the nine yield-related characters on chilli yield per plant.

Individual fruit weight (0.464) had the most significant positive direct effect on fruit yield, followed by the number of fruits per plant (0.421), fruit diameter (0.385), and fruit length (0.367) (Table 2). Other researchers (Chattopadhyay et al., 2011; Kumar et al., 2012; Sarkar et al., 2009; Ullah et al., 2011) have also reported a positive and direct effect on the produce yield per plant, which is consistent with the results of the current investigation. It is intriguing that these characteristics also demonstrated a substantial positive correlation with yield. Consequently, they should be regarded as critical selection criteria for the enhancement of chilli yield. Individual fruit weight (0.908) and number of fruits per plant (0.400) had a greater indirect positive effect on chilli fruit yield. Other attributes, such as the quantity of seeds per fruit and the height of the plant, also demonstrated a direct positive impact on fruit yield; however, the magnitudes were negligible (Table 2). Days to 50% green fruit maturity had the highest direct negative effect (-0.279) on fruit yield followed by days to 50% fruit setting (-0.677) and days to 50% flowering (-0.155). The residual effect of the path analysis was found to be very low (0.085), indicating that the characters examined in the study were adequate and justified.

Table 2. Genotypic (G) and phenotypic (P) path coefficients indicating direct and indirect effects, respectively, of yield related characters on green fruit yield in 28 chilli genotypes

		DFTF	DFTS	DFTM	FRLN	FRDM	FRPP	IFRW	NSPF	PLHT
DFTF	G	**-0.155**	-0.772	-3.276	0.073	0.149	0.069	0.282	0.052	0.005
	P	**0.048**	-0.026	0.025	-0.002	-0.005	0.009	0.164	-0.003	0.004
DFTS	G	-0.176	**-0.677**	-2.364	-0.056	-0.013	0.218	0.052	-0.031	0.014
	P	0.016	**-0.079**	0.062	0.005	0.001	0.176	0.089	0.004	0.026
DFTM	G	-0.182	-0.576	**-2.779**	-0.050	0.044	0.133	0.095	-0.020	0.012
	P	0.015	-0.062	**0.078**	0.005	-0.004	0.104	0.180	0.003	0.022
FRLN	G	-0.031	0.104	0.382	**0.367**	0.021	-0.011	0.210	0.067	0.005
	P	0.002	0.011	-0.011	**-0.034**	-0.003	-0.009	0.403	-0.010	0.011
FRDM	G	-0.060	0.022	-0.315	0.020	**0.385**	-0.088	0.317	0.117	-0.005
	P	0.004	0.002	0.006	-0.002	**-0.051**	-0.077	0.511	-0.017	-0.006
FRPP	G	-0.025	-0.350	-0.878	-0.010	-0.080	**0.421**	0.033	0.010	0.020
	P	0.001	-0.035	0.020	0.001	0.010	**0.400**	0.059	-0.004	0.035
IFRW	G	-0.094	-0.075	-0.571	0.166	0.263	0.030	**0.464**	0.145	0.009
	P	0.009	-0.008	0.016	-0.015	-0.029	0.026	**0.908**	-0.022	0.017
NSPF	G	-0.042	0.109	0.294	0.130	0.238	0.022	0.353	**0.190**	0.003
	P	0.005	0.009	-0.007	-0.009	-0.025	0.044	0.571	**-0.035**	0.007
PLHT	G	-0.023	-0.296	-1.057	0.062	-0.060	0.270	0.133	0.017	**0.032**
	P	0.003	-0.032	0.027	-0.006	0.005	0.221	0.237	-0.004	**0.064**

DFTS, DFTS and DFTM designate days to 50% flowering, 50% fruiting, and 50% green fruit maturity, respectively; FRLN and FRDM implies fruit length (cm), and fruit diameter (mm), respectively; FRPP designates number of fruits/plants, whereas IFRW is individual fruit weight (g), and NSPF is numbers of seeds/fruit; FYPP: fruit yield/plant (kg), PLHT: plant height (cm)

CONCLUSION

The path coefficient analysis results demonstrated that the fruit yield per plant in chillies could be enhanced by making an effective selection based on the individual fruit weight, number of fruits per plant, fruit length, and diameter. It is evident that the yield could be enhanced through direct selection based on these characteristics.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this paper.

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