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Correlation Studies and Path Analysis for Yield Enhancing Attributes in Hot Pepper

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ABSTRACT

The present study was carried out during March to September, 2018 at the Experimental Farm of the Regional Horticultural Research and Training Station (RHRST) Dhaulakuan, Dr. Yashwant Singh Parmar University of Horticulture & Forestry, Solan, HP (173230), India to investigate the interrelationship between various yield-associating factors and to construct an efficient trait for indirect selection using 21 chilli genotypes. In the study, the relationship between characteristics and path analysis showed genotypic as well as phenotypic correlation of green fruit yield plant^{-1} with the number of fruit plant^{-1}, the weight of the fruit at edible maturity, and the diameter of the fruit. On the other hand, the dry matter of the fruit, the height of the plant, the number of seeds plant^{-1} and thousand seed weight showed a big positive correlation with red fruit yield plant^{-1}. Path analysis at genotypic as well as phenotypic level showed maximum direct effect on number of fruit plant^{-1}, weight of fruit at edible maturity and fruit diameter towards green yield plant^{-1}. Conversely, fruit dry matter content, plant height and number of seeds fruit^{-1} and 1000 seed weight had direct effect on red fruit yield plant^{-1}. The present outcome provided an insight that the better yield contributing genotypes might be utilized in future hot chilli improvement programme.

KEYWORDS: Chilli, correlation, genotypic, phenotypic, path analysis, yield

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1. INTRODUCTION

Chilli, also known as hot pepper, is the most valuable and profitable cash crops (Singh et al., 2022a) widely harvested for its dried red or fresh green fruits and is one of the essential spices in every tropical household (Pandiyaraj et al., 2017) in terms of taste, color, pungency, and flavor (Sun et al., 2014; Tilahun et al., 2022; Komala et al., 2023). In addition to being used as a food supplement, it is also used for extraction of oleoresin and is rich in vitamin A, C, E, as well as antioxidants which act as anti-cancer agents (Chakrabarty et al., 2017; Vidya Sagar et al., 2022). Capsaicinoids in chilli contains capsaicin and dihydrocapsaicin which are responsible for about 90% of the spicy taste and it is also important in the food industry (Nishoni et al., 2016; Lyu et al., 2019).

India has overtaken China as the world's largest producer, consumer and exporter of chili. The major chilli producing countries accounting for more than 85% of the world production are India, China, Korea, Japan, Spain, Nigeria, Pakistan Indonesia, Mexico etc. Chilli is cultivated in an area of 1.9 mha with an annual production of 34.5 mt of green fruits and 3.9 mt of dry peppers and productivity of 18.15 t ha^{-1} and 2.05 t ha^{-1} respectively in the world (Anonymous, 2017). In India, chilli is cultivated in the states of Andhra Pradesh, Telangana, Maharashtra, Karnataka, Orissa and Tamil Nadu forming more than 70% acreage. In India, green chillies are grown in area of 391000 ha with the production of 4.06 mt and dry chilli covers an area of 743000 ha with annual production of 1.9 million tonnes (Anonymous, 2021a). The export of chillies from India to other countries is increasing year after year. The export of 45,369 mt resulted in earning of $41 million in 2019. (Anonymous, 2021b). In Himachal Pradesh, chillies are cultivated in 1218 ha with an annual production of 14528 mt and productivity of 11.93 mt ha^{-1}. The district Sirmour of Himachal Pradesh is the leading producer of chillies being cultivated in an area of 458 ha with the production of 5980 MT (Anonymous, 2018). In view of increased demand for export and consumption, there is a need to improve the quality and to develop resistance against major diseases and pests of the crop (Swapan et al., 2017; Naves et al., 2022). The success of a breeding programme, particularly a selection-based breeding programme, is contingent upon the availability of breeding sources (Sharma et al., 2020; Khan et al., 2020). For selecting heritable traits, estimating genetic parameters and their relation to each other is important (Deepo et al., 2020; Singh et al., 2022b). Knowing the relationships between different plant traits is helpful when selecting traits for crop improvement (Kumar et al., 2021). However, this correlation insight is just misleading because the correlation observed is not always accurate, so it may not give a complete picture of each component trait in predicting crop yield (Okuyama et al., 2004). Therefore, inter component correlation analysis is determined by path-coefficient analysis (Bijalwan et al., 2016; Sekhon et al., 2019). The purpose of path coefficient analysis is to quantify the source of the association and to determine the direct and indirect effects of one character on the yield of a crop (Dewey and Lu, 1959; Aman et al., 2020; Kalapchieva et al., 2021). The aim of the study was to evaluate the genotypes and phenotypes associated with yield contributing traits, as well as to conduct path analysis to determine the direct or indirect effects of the characters on the crop yield.

2. MATERIALS AND METHODS

This study was carried out during the *kharif* season i.e. March to September of 2018 at the Experimental Farm of Regional Horticultural Research and Training Station Dhaulakuan, Distt. Sirmour (HP) affiliated to Dr. YSP University of Horticulture and Forestry, Solan (Himachal Pradesh), India.The design of the experiment was based on a randomised complete block design (RCBD). Twenty-one genotypes (20 genotypes+1 standard check) were replicated three times and planted at a 45×45 cm^2 spacing from row to row and from plant to plant. The recommended cultivation practices for a healthy crop were followed.Observation was conducted on five plants that were chosen for their green fruit traits. These traits included the days from which the plant was at 50% flowering, days to first green fruit was harvested, fruit diameter (cm), fruit length (cm), the number of fruits $plants^{-1}$, the dry matter content of fruit (%), the number of seeds $fruit^{-1}$, the weight of the fruit at edible maturity (g) capsaicin content (%), red fruit yield $plant^{-1}$ (g) and 1000-seed weight (g). Additionally, a correlation was determined and a path coefficient analysis was conducted to determine the yield of the green fruits yield $plant^{-1}$ (g). The path analysis was employed to determine the direct and indirect contribution of various characteristics to yield, as elaborated by Dewey and Lu (1959).

3. RESULTS AND DISCUSSION

3.1. Correlation studies

In this study, the correlation coefficient between various characters was calculated for all possible combinations at genotypic as well as phenotypic levels (Table 1 and Table 2). The genotypic correlation coefficient was generally larger than the phenotypic correlation coefficient, suggesting that reliable selection for desired genotype based on phenotypic expression can be made for chilli based on Ajjapplavara et al., 2005).

3.1.1. The genotypic and phenotypic interrelationships of different characters on green fruit yield $plant^{-1}$

The green fruit yield for each plant was statistically significant and had a positive correlation with the number

Table 1: The Genotypic and phenotypic coefficients of correlation among various characters of chilli on green fruit yield plant^{-1} (*Capsicum annuum* L.)

		DTFF	DTGP	FL	FD	NOF	FWT	GFYP
DTFF	G	1.000	0.955*	-0.427*	-0.592*	-0.751*	-0.424*	-0.750*
	P	1.000	0.925*	-0.397*	-0.558*	-0.706*	-0.379*	-0.692*
DTGP	G		1.000	-0.471*	-0.529*	-0.770*	-0.373*	-0.737*
	P		1.000	-0.440*	-0.496*	-0.731*	-0.343*	-0.688*
FL	G			1.000	-0.150	0.347*	-0.018	0.211
	P			1.000	-0.147	0.330*	-0.003	0.197
FD	G				1.000	0.644*	0.728*	0.778*
	P				1.000	0.620*	0.701*	0.744*
NOF	G					1.000	0.441*	0.896*
	P					1.000	0.418*	0.855*
FWT	G						1.000	0.719*
	P						1.000	0.671*
GFYP	G							1.000
	P							1.000

*p=0.05; DTTF: days to 50% flowering; FWT: fruit weight at edible maturity; DTGP: days to first green fruit picking; NOF: number of fruits plant^{-1}; FL: fruit length; GFYP: green fruit yield plant^{-1}; FD: fruit diameter

Table 2: Correlation coefficients at genotypic and phenotypic levels among different characters in chilli for red fruit yield plant-1 (*C. annuum* L.)

		DTRM	PH	FDM	NOS	TSW	CC	RFYP
DTRM	G	1.000	-0.483*	-0.337*	-0.371*	-0.517*	-0.322*	-0.674*
	P	1.000	-0.465*	-0.320*	-0.342*	-0.503*	-0.316*	-0.657*
PH	G		1.000	0.436*	0.272*	0.296*	0.251*	0.478*
	P		1.000	0.389*	0.244	0.293*	0.241*	0.462*
FDM	G			1.000	0.394*	0.732*	0.607*	0.669*
	P			1.000	0.383*	0.681*	0.579*	0.643*
NOS	G				1.000	0.514*	0.101	0.646*
	P				1.000	0.489*	0.095	0.612*
TSW	G					1.000	0.461*	0.727*
	P					1.000	0.450*	0.699*
CC	G						1.000	0.329*
	P						1.000	0.322*
RFYP	G							1.000
	P							1.000

*Significant at p=0.05 level of significance; Where, DTMR: days to first red fruit maturity; TSW: 1000 seed weight; PH: plant height; CC: capsaicin content; FDM: fruit dry matter content; RFYP: red fruit yield plant^{-1}; NOS: no. of seeds fruit^{-1}

of fruits plant^{-1} (0.896, 0.855), the diameter of the fruit (0.778, 0.744), the weight of the fruit at edible maturity (0.719, 0.671), and the height of the plant (-0.750, -0.692). However, the correlation was negative and significant for the number of days until 50% flowering (-0.750, -0.692), the days until first green fruit picking (-0.737, -0.688) at phenotypic as well as genotypic levels. There was a strong and positive relationship between the weight of the fruit at edible maturity and the diameter of the fruit (0.728, 0.701) and the number of fruits plant^{-1} (0.441, 0.418). However, there was a big negative relationship between the days to get 50% flowering and the days to get green fruit picking, with the correlation being (-0.424 -0.379) and days to first green fruit picking (-0.373 (-0.343). The number of fruit plant^{-1} was positively correlated with the diameter of the fruit (0.644,0.620) and the length of the fruits (0.347, 0.330). Fruit length and diameter were negative but significantly correlated with the days to 50% of flowering and the days to 1st green fruit picking. Fruit diameter and fruit length were positively correlated with each other at the genotypic level and at the phenotypic level as well. On the other hand, fruit length and diameter were negatively correlated with each other. However, fruit length and fruit diameter showed positive and significant correlations with the days to 50% flowering (0.955, 0.925) at genotypically and phenotypically.

In line with the findings of the current study, Farhad et al. (2008), found a positive and significant relationship between green fruit yield plant^{-1} and number of fruits plant^{-1} (0.7474; 0.6679) and fruit weight at edible maturity (0.5087, 0.4698) at genotypic and phenotypic level respectively. There is a positive but non-significant relationship between green fruit yield plant^{-1} and the length of the fruit while, positive and significant relationship between green fruit yield plant^{-1} and fruit girth (0.4360, 0.3889) as reported by Farhad et al. (2008) at both the levels. The results were consistent with Krishnamurthy et al. (2013) which reported a negative significant correlation between green fruit yield plant^{-1} and days to 50% flowering (-0.11; -0.10 genotypically and phentypically.

3.1.2. The genotypic and phenotypic interrelationships of different characters on red fruit yield plant^{-1}

In addition, the correlation coefficient among characters showed significant and positive correlations with thousand seed weight at genotypic (0.727, 0.699), fruit dry matter content (0.669, 0.634), number of seeds fruit^{-1} (0.646, 0.612), plant height (0.478, 0.462) and capsaicin content (0.329, 0.322) at genotypic as well as phenotypic level. The days to first maturity of red fruit were negatively correlated at both genotypic (0.674) and phenotypic (0.657) levels with the red fruit yield plant^{-1}. Genotypically and phenotypically, the capsaicin content of fruit was significantly and positively associated with the dry matter content of the seed (0.607 and 0.579), and the thousand seed weight (0.461 and 0.450) as well as the plant height at the 0.251 and the 0.241 respectively.

The correlation between thousand seed weight, fruit dry matter content (0.732 and 0.681), seed number fruit^{-1} (0.514 and 0.489) and plant height (0.296 and 0.293) at the genotypic level was significant and positive. Seed number fruit^{-1} was significantly correlated to fruit dry matter content at both levels (0.394 and 0.383), however, plant height was only significant with this trait. The fruit dry matter content showed a positive and significant relationship with the plant height (0.436 and 0.389) and the number of days until the first red fruit maturity showed a significant but negative relationship with all parameters examined.

The results concurred with the results of Farhad et al. (2008) which found a significant and positive relationship between the fruit yield of each plant and the number of seed plant^{-1} (0.3530, 0.2954) and the 1000-seed weight (0.3620, 0.3026). Krishnamurthy et al. (2013) reported a significant positive relationship between the red fruit yield plant^{-1} with the 100 seed weight, but a negative significant relationship between red fruit yield plant^{-1} and plant height. A study by Pandiyaraj et al. (2017) found a positive and significant relationship between the dry fruit yield plant^{-1} with plant height and capsaicin concentration. In line with the findings of this study, Amit et al. (2014) also found a strong and consistent relationship between the number of seed fruit^{-1} and the plant height at the genotypic level.

3.2. Path coefficient analysis

The path coefficient analysis by Dewey and Lu (1959) gives a realistic basis for assigning appropriate weights to different variables while constructing a pragmatic yield development programme. It is useful for classifying correlation coefficient as direct or indirect effect of independent variables on a dependent variable.In this study, green fruit yield plant^{-1} was used as a dependent variable and the other characters were seen as independent variables.The results of path coefficient analysis are presented at both the genotype and phenotype level, demonstrating the respective direct and indirect impacts of significant characters on green fruit yield by plant^{-1}, as well as the influence of red fruit yield plant^{-1} have been summarizes in Table 3 and 4.

3.2.1. Analysis of path coefficient on green fruit yield plant^{-1}

The estimation of direct and indirect impacts on green fruit yield plant^{-1} is based on a correlation between genotypes and phenotypes given in Table 3. The path analysis revealed that the number of fruits had the greatest positive direct effect on the yield of green fruit plant^{-1} at genotypic level (0.636) followed by the weight of the fruit at edible maturity (0.365) and the diameter of the fruit (0.050). Conversely, the days to 50% flowering (0.086) and the days to the first green fruit picking (0.002) had genotypically negative direct effects on green fruit yield plant^{-1}. The number of fruits plant^{-1} (0.410) and the weight of the fruit at edible maturity (0.266) showed positive indirect effect on the green fruit yield via. diameter of the fruit. All the traits had a negative indirect effect on the yield of green fruit from days to 50% of flowering and from days to the first green fruit picking. The phenotypic path analysis revealed that the highest direct effect on

Table 3: The path coefficient analysis demonstrates the direct and indirect impact of characters on green fruit yield plant^{-1} at the levels of genotypic as well as phenotypic

		DTFF	DTGP	FD	NOF	FWT	GFYP
DTFF	G	-0.086	-0.002	-0.030	-0.478	-0.155	-0.750*
	P	-0.055	-0.048	-0.059	-0.410	-0.119	-0.692*
DTGP	G	-0.082	-0.002	-0.027	-0.490	-0.136	-0.737*
	P	-0.051	-0.052	-0.053	-0.425	-0.108	-0.688*
FD	G	0.051	0.001	0.050	0.410	0.266	0.778*
	P	0.031	0.025	0.107	0.360	0.220	0.744*
NOF	G	0.065	0.001	0.032	0.636	0.161	0.896*
	P	0.039	0.038	0.066	0.581	0.132	0.855*
FWT	G	0.037	0.001	0.037	0.280	0.365	0.719*
	P	0.021	0.018	0.075	0.243	0.315	0.671*

Residual (genotypic level): 0.06209; residual (phenotypic level): 0.13867; *p=0.05

Table 4: The path coefficient analysis demonstrates the direct and indirect effect of characters on red fruit yield plant^{-1} at the levels of genotypic and phenotypic

		DTRM	PH	FDM	NOS	TSW	CC	RFYP
DTRM	G	-0.388	-0.018	-0.128	-0.101	-0.082	0.044	-0.674*
	P	-0.367	-0.034	-0.101	-0.089	-0.100	0.035	-0.657*
PH	G	0.187	0.037	0.166	0.074	0.047	-0.034	0.478*
	P	0.170	0.074	0.123	0.064	0.059	-0.027	0.462*
FDM	G	0.130	0.016	0.380	0.108	0.117	-0.082	0.669*
	P	0.117	0.029	0.316	0.100	0.136	-0.064	0.643*
NOS	G	0.144	0.010	0.150	0.273	0.082	-0.013	0.646*
	P	0.125	0.018	0.121	0.261	0.098	-0.011	0.612*
TSW	G	0.201	0.011	0.279	0.140	0.160	-0.063	0.727*
	P	0.184	0.022	0.215	0.128	0.200	-0.050	0.699*
CC	G	0.125	0.009	0.231	0.026	0.074	-0.136	0.329*
	P	0.116	0.018	0.183	0.027	0.090	-0.112	0.322*

Residual (genotypic level) : 0.21857; residual (phenotypic level): 0.26089; *p=0.05

yield plant^{-1} was the number of fruits (0.581), followed by the weight of the fruit at edible maturity (0.315) and the diameter of the fruit (0.107). However, the direct effect on yield was negative for days from 50% flowering to the first green fruit picking at (-0.055) and (-0.052).

The direct effects by the number of fruits produced by each plant on the green fruit yield plant^{-1} had been demonstrated in a number of studies, including those conducted by Farhad et al. (2008), Hasanuzzaman and Golam (2011), Chattopadhyay et al. (2011) of 0.8513, 0.501 and 0.979 respectively. A positive direct effect on the diameter of the fruit has been observed at the phenotypic level by Farhad et al. (2008). Krishnamurthy et al. (2013) showed, a negative direct effect on the number of days up to 50% flowering has been observed in the presence of green fruit yield plant^{-1}.

3.2.2. Analysis of path coefficient on red fruit yield plant^{-1}

A review of the genotype path coefficient analysis revealed that the most significant direct positive effect (Table 4) on the red fruit yield per plant was imposed by the fruit dry matter (0.380), followed by the number of seeds per fruit (0.273), the weight of seeds per thousand (0.160), and the height of the plant (0.037). Conversely, a direct negative impact was made by the days until the first red fruit maturing (-0.388) and the capsaicin (-0.136) content. The path coefficient analysis at the phenotypic level revealed that the maximum positive direct effect on the red fruit yield Plant^{-1}

was observed (0.316), followed by number of seeds (0.261), for the thousand seed weight (0.200), and the plant height (0.074). Conversely, a direct negative contribution to the red fruit yield was observed at the day to first red fruit maturity and at the capsaicin content level (0.112).

The direct effects of plant height have also been observed and reported in other studies, such as Solanki et al. (1986); Pandiyaraj et al. (2017). A negative direct correlation between capsaicin and the yield of fruit plant^{-1} has previously been observed by Yatung et al. (2014). The direct negative correlation between days to red maturity and yield plant^{-1} was observed in a study conducted by Hasanuzzaman and Golam (2011).In path analysis, residual effect refers to the degree to which the independent component (independent factors) explain the variation of the dependent variable viz., green fruit yield plant^{-1} and red fruit yield plant^{-1}. Residual factors had a normal impact on yield plant^{-1} at both genotypic and phenotypic levels, thus, some minor yield components were not included in the programme to contribute yield.

4. CONCLUSION

The present study provided a positive significant correlation and direct effects of fruit yield per plant with number of fruits plant^{-1}, weight of fruit and diameter of fruit. Based on these direct relationship of these traits, selection of desirable genotypes would prove helpful for the further breeding programme.

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