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Assessment of relationship among yield and fruit quality traits in chilli germplasm through correlation analysis

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Abstract
Chilli is one of the most significant vegetable and spice crops globally. Simultaneous selection of a combination of associated characters is always targeted in crop breeding programs. Expression of traits leading to plant phenotype is the result of associated inheritance of many interrelated genes working together. Correlation coefficients were assessed in seventy-two genotypes in chilli for twenty different quantitative characters. Phenotypic correlation co-efficient analysis revealed significant positive association of number of fruits per plant, plant spread in north south, individual fruit weight, stem girth, plant spread in east west, fruit length and plant height with fruit yield per plant. However, the peroxidase activity was found to be negatively and significantly associated with fruit yield per plant. Correlations among yield component traits revealed positive and significant association of individual fruit weight with fruit diameter, fruit length, whereas showed negative significant relation with number of fruits per plant. Plant spread in east west direction and north south, plant height and stem girth had significant positive association with number of fruits per plant. Among the quality parameters, the trait capsaicin content had positive and highly significant correlation with fruit diameter and individual fruit weight, but negative with dry matter content, Ascorbic acid and stem girth.

Keywords: Chilli, genotypes, correlation coefficient, association

Introduction

Chilli (*Capsicum* spp.) are among the most significant vegetable crops globally owing to their economic and industrial uses as well as the health benefitting value (Singh *et al*., 2017) [24]. Globally, it is the second-most important vegetable crop after tomato in terms of economic value (Kumari *et al.,* 2018) [14]. Chilli has a chromosome number of 2n = 24 (Carrizo Garcia *et al*., 2016) [5] So far, the genus *Capsicum* has been identified to contain more than 30 distinct species (Gayathri *et al*., 2022) [10], five of which have been domesticated *viz., C. annuum* L, *C. baccatum* L, *C. chinense* Jacq., *C. frutescens* L., and *C. pubescens* (Saisupriya *et al.,* 2022) [21]. The most widely grown species is *C. annuum* L. being grown for both pungent and non-pungent fruits. Chilli is a prominent source of minerals and vitamins including steam-volatile oil, fatty oils, carotenoids, protein and fibre (Bosland, 1996) [4]. Capsaicin, the chief constituent of fruit responsible for pungency has significant pharmaceutical value and also used in cosmetics (Osuna-Garcia *et al.,* 1998; Marin *et al*., 2004) [18, 16].

Chilli is a genetically self-pollinating chasmogamous crop (Lemma, 1998) [15], but because of its high outcrossing rate, it has been grouped as an often-cross-pollinated crop with an out crossing rate of up to 66.40 per cent (Singh *et al*., 2017) [24]. Currently, India is the leading producer, consumer and exporter of hot peppers in the world with an area of 4.18 lakh hectares and production of 45.05 lakh tonnes (Anonymous, 2021) [2]. Yield is the major determinant being targeted for improvement, but is a complex quantitative trait influenced by a number of yield-contributing parameters (Pujar *et al.,* 2017) [20]. It is therefore necessary to study the degree of association between yield and yield components as well as quality traits for efficient utilization of the genetic stock for simultaneous improvement of several targeted traits (Srinivas *et al.,* 2020) [27].

Expression of traits leading to plant phenotype is the result of associated inheritance of many interrelated genes working together (Chavan *et al.*, 2021) [7]. Knowledge of the correlation coefficient as a measure of the degree and direction of relationship between different characters would allow the breeder to make decisions about the yield complaint characters to be considered for yield improvement as well as to achieve the desired combination of traits (Meena *et al*., 2016) [17]. The correlations can exist at the genotypic and phenotypic levels (Srinathareddy *et al.*, 2019) [26]. Genotypic correlation reveals the intrinsic relationship between different variables owing to the existence of linkage or the pleiotropic effect of genes or the both (Harland, 1939) [12] which in turn is manifested as phenotypic correlation (Singh *et al*., 2017) [24]. Yield in any crop can be enhanced through indirect selection for highly heritable and associated traits (Singh 1983) [23]. So, the knowledge regarding association of various simply inherited traits with targeted economic characters like yield and among themselves would provide necessary information for indirect selection of economic characters. Correlation coefficient studies provide better understanding of yield components which help plant breeder during selection (Johnson *et al*., 1955). The potential progress in accomplishing the objective demands the knowledge of inter-relationships among various characters, which helps the breeder in the formulation of simultaneous selection scheme. Correlation between any two component characters may be positive or negative. Positive correlation would result in improvement of both the characters simultaneously, but in negative correlation increase in the improvement in one variable would hinder the improvement of the other character. Therefore, there is necessity to have information regarding association among the traits themselves and the targeted trait according to the breeding objective. In the present study, correlation co-efficient analysis was carried for the studied yield and fruit quality traits using chilli germplasm.

Material and Methods

The present investigation was carried out during *kharif* 2022 at the Research field, Department of Biotechnology and Crop Improvement, College of Horticulture, Bengaluru. The experimental material for the present study consisted of 68 chilli genotypes and 4 checks that included few advanced selections and accessions collected from across India and were evaluated for yield and fruit quality traits. Seventy-two chilli genotypes including four checks *viz*., Pusa Jwala, Pusa Sadabahar, Punjab Tej, Punjab CH-21 were evaluated to assess the correlation between yield and yield attributing traits as well as with fruit quality traits.

The experiment was laid out in Augmented block design II (Federer, 1961) [9] with four compact blocks, each block comprising of 17 genotypes and four checks with a spacing of 60 cm x 45 cm. The crop raised as per the recommended package of practices. Five plants were randomly selected and tagged from each genotype for recording observations on various growth and yield parameters of green chilli. The average of five plants for all the measured traits were used for correlation coefficient analysis. Observations recorded for all the studied (20) characters were considered to understand the nature of association present between the characters.

Correlation coefficient analysis: Pearson correlation measures the existence and strength (given by the coefficient r between -1 and +1) of a linear relationship between two variables. The correlation co-efficients were worked out to determine the degree and direction of association among the growth, yield and quality parameters. The analysis of variance and covariances were computed by the method designed by Singh and Chaudhary (1979) [23] and correlation coefficients were computed using the formula suggested by Al-Jibourie *et al.* (1958) [1].

Phenotypic correlation coefficient between character x and y

$$r_{xy\ (p)} = \frac{COV_{xy(p)}}{\sqrt{V_{x(p)}\ x\ V_{y(p)}}}$$

Where,

COV_{xy} (p) = Phenotypic covariance between characters x and y

Vx (p) = Phenotypic variance of character x

Vy (p) = Phenotypic variance of character y

The significance of correlation coefficients (r) was tested by comparing ‘r’ value at (n-2) error degree of freedom against values given in Yates *et al.* (1963) table at the probability levels of 0.05 and 0.01 where “n” denotes the total number of pairs of observations used in the analysis.

$$t = \sqrt{r\ (n-2/1-r^2)}$$

where n is the number of pairs of observations.

Results and Discussion

Correlation co-efficients were worked out for all the studied (20) characters to understand the nature of association present between characters. Phenotypic correlation co-efficient analysis (Table 1) revealed significant positive association of number of fruits per plant (0.572), plant spread in north south (0.480), individual fruit weight (0.360), stem girth (0.335), plant spread in east west (0.328), fruit length (0.313) and plant height (0.273) with fruit yield per plant. However, the quality trait peroxidase activity was found to be significantly associated with fruit yield per plant (-0.218) in a negative direction.

Association among the yield attributing traits indicated significant positive correlation of number of fruits per plant with plant spread in east west direction (0.436) and north south (0.431), plant height (0.284) and stem girth (0.280). Stalk length was positive and significantly correlated with fruit length (0.319) and stem girth (0.217). Plant spread in east-west direction was positive and significantly associated with plant height (0.565), spread in north-south direction (0.455), stem girth (0.347). Plant spread in north-south direction was positive and significantly associated with plant height (0.443) and stem girth (0.356). Positive and significant association of stem girth was with plant height (0.533) and number of primary branches (0.346). The association of number of secondary branches was positive and significant with number of primary branches (0.792). The trait days to 50% of flowering revealed positive significant correlation with days to first harvest (0.780) and stem girth (0.307). Days to first harvest exhibited positively significant interrelationship with stem girth (0.284). Individual fruit weight was positive and significantly correlated with fruit diameter (0.607), fruit length (0.256), whereas showed negative significant relation with number of fruits per plant (-0.350).

Among the quality parameters, it has been observed that the trait capsaicin content was found to have positive and highly significant correlation with fruit diameter (0.294) and individual fruit weight (0.288) but it was negative and significantly associated with dry matter content (-0.282), Ascorbic acid (-0.270) and stem girth (-0.227). Likewise, dry matter content in fruit was positive and significantly associated with stalk length (0.240), plant height (0.236) and stem girth (0.232). Ascorbic acid content in the green fruit was positive and significantly associated with plant spread in east-west direction (0.267) and plant height (0.266). Total phenol content exhibited positive significant correlation with days to 50% flowering (0.240), but negatively and significantly allied with oleoresin content (-0.244).

Table 1: Phenotypic correlation coefficients among yield and fruit quality parameters in germplasm accessions of chilli

	PHT	NPB	NSB	GTH	EW	NS	DTF	DTH	NFP	FL	FD	SL	IFW	FYP	OLE	DM	VC	TP	POD	CAP
PHT	1.000	0.205	0.151	0.533**	0.565**	0.443**	0.073	0.028	0.284**	0.071	-0.026	0.212	-0.018	0.273*	0.096	0.236*	0.266*	0.009	-0.026	-0.040
NPB		1.000	0.792**	0.346**	0.091	0.137	0.125	0.126	0.019	-0.189	-0.029	0.125	-0.033	0.044	0.134	0.152	0.087	0.024	0.278*	0.127
NSB			1.000	0.160	0.008	0.162	0.014	-0.028	0.049	-0.172	-0.128	0.071	-0.162	-0.090	0.179	0.135	0.030	-0.004	0.223*	0.111
GTH				1.000	0.347**	0.356**	0.307**	0.284**	0.280**	-0.122	0.080	0.217*	0.012	0.335**	0.002	0.232*	0.094	0.055	0.043	-0.227*
EW					1.000	0.455**	0.115	-0.048	0.436**	0.146	-0.047	0.155	-0.161	0.328**	0.012	0.166	0.267*	0.096	-0.141	-0.211
NS						1.000	-0.014	-0.006	0.431**	0.204	0.113	0.125	0.037	0.480**	0.078	0.161	0.150	-0.041	-0.154	-0.072
DTF							1.000	0.780**	0.124	-0.161	0.139	-0.052	0.059	0.143	0.006	0.071	0.102	0.240*	-0.082	-0.144
DTH								1.000	-0.064	-0.206	0.120	0.014	0.116	0.003	0.023	-0.037	-0.042	0.195	0.018	-0.110
NFP									1.000	0.105	-0.185	0.036	-0.350**	0.572**	-0.044	0.166	0.037	0.200	0.013	-0.159
FL										1.000	-0.111	0.319**	0.256*	0.313**	0.144	0.100	0.048	0.111	-0.320**	-0.082
FD											1.000	-0.004	0.607**	0.195	-0.020	-0.052	-0.030	-0.128	-0.031	0.294**
SL												1.000	0.123	0.136	0.101	0.240*	0.094	-0.018	-0.003	-0.180
IFW													1.000	0.360***	0.025	-0.048	-0.051	-0.111	-0.237*	0.288**
FYP														1.000	-0.041	0.167	0.102	0.095	-0.218*	-0.063
OLE															1.000	0.162	-0.061	-0.244*	0.225*	-0.214
DM																1.000	0.080	0.020	0.082	-0.282**
VC																	1.000	0.047	0.012*	-0.270*
TP																		1.000	-0.126	-0.044
POD																			1.000	0.075
CAP																				1.000

*Significant at 5% **Significant at 1%

PHT	Plant height (cm)	DTH	Days to first harvest	CAP	Capsaicin content (%)
NPB	Number of primary branches per plant	NFP	Number of fruits per plant	OLE	Oleoresin content (%)
GTH	Stem girth (mm)	FD	Fruit diameter (mm)	VC	Ascorbic acid (mg/100g)
E-W	Plant spread from east to west (cm)	SL	Stalk length (cm)	TP	Total phenols (mg/100g)
N-S	Plant spread from north to south (cm)	IFW	Individual fruit weight (g)	POD	Peroxidase estimation (activity/min/g)
DTF	Days to fifty percent flowering	FYP	Fruit yield per plant (g)		

Peroxidase activity showed positive and significant association with number of primary (0.278) and secondary branches (0.223) and oleoresin content (0.225). Further, it was negatively and significantly correlated with fruit length (-0.320), individual fruit weight (-0.237) and fruit yield per plant (-0.218).

The inter-trait phenotypic correlations among yield, yield component traits and quality traits using 72 test genotypes revealed significant positive association of number of fruits per plant, plant spread in north south, individual fruit weight, stem girth, plant spread in east west, fruit length and plant height with fruit yield per plant. Enhanced plant growth, stem girth, a greater number of branches and larger fruits eventually resulted in higher green chilli yields. In the present study, the high yielding ability of the genotypes could be explained due to the better combination of these positively associated traits, which are also easily measurable and thus could be considered as principal yield determinant traits to score large number of plants in chilli yield selection programs. These correlated characters need to be taken into consideration for potential progress in accomplishing yield enhancements. These inherent associations of yield traits with green chilli yield could be attributed to the genetic linkage among the favorable genes for these traits and further the extent of association and co-heritability might depend upon the number of genes involved in a particular trait combination. These results are in accordance with that of Datta and Jana (2010) [8], Chattopadhyay *et al*. (2011) [6], Pandiyaraj *et al.* (2017) [19], Pujar *et al*. (2017) [20], Sran and Jindal (2019) [25] and Harishkumar *et al.* (2020) [11]. However, the quality trait peroxidase activity was found to be significantly associated with fruit yield per plant in a negative direction.

Association among the yield attributing traits indicated significant positive correlation of number of fruits per plant with plant spread in east west direction and north south, plant height and stem girth Tilahun *et al*. (2022) [30], Chavan *et al*. (2021) [7] and Pandiyaraj *et al*. (2017) [19]. Plant spread in east-west direction was positive and significantly associated with plant height, spread in north-south direction, stem girth. Whereas number of primary branches was positive and significantly correlated with number of secondary branches as reported by previous workers like Chattopadhyay *et al.* (2011) [6], Pandiyaraj *et al.* (2017) [19] and Bekele *et al.* (2022) [3]. Positive and significant association of stem girth was with plant height and number of primary branches. The trait days to 50% of flowering revealed positive significant correlation with days to first harvest and stem girth. Individual fruit weight was positive and significantly correlated with fruit diameter, fruit length, whereas showed negative significant relation with number of fruits per plant. These positive inter-associations between yield componential traits might be attributed to the desirable combinations of genes as well as multiple effects of genes which can be used for simultaneous improvement of target traits (Singh *et al*., 2017; Shweta *et al.* (2018) [22]; Srinathareddy *et al.* (2019) [26]; Chavan *et al*., 2021) [24, 7].

Capsaicin content was positively associated with fruit diameter and individual fruit weight but it was negative and significantly associated with dry matter content, Ascorbic acid and stem girth. Likewise, dry matter content in fruit was positive and significantly associated with stalk length, plant height and stem girth [Shweta *et al.* (2018) [22], Srinathareddy *et al.* (2019) [26], Chavan *et al.* (2021) [7], Srinivas *et al.* (2020)] [27]. Ascorbic acid content in the green fruit was positive and significantly associated with plant spread in east-west direction and plant height. Peroxidase activity showed positive and significant association with number of primary and secondary branches and oleoresin content, but was negatively and significantly correlated with fruit length, individual fruit weight and fruit yield per plant. Significant positive association among quality traits could be exploited for selection of genotypes with desired combination of traits. Magnitude and direction of association has to be considered in determining the better combination of yield and nutritional traits (Meena *et al*., 2016; Singh *et al*., 2017; Srinathareddy *et al*., 2019; Srinivas *et al*., 2020; Chavan *et al*., 2021) [17, 26, 24, 27, 7].

Conclusion
Significant positive association among yield traits as well as fruit quality traits could be exploited for selection of genotypes with desired combination of traits. Magnitude and direction of association has to be considered in determining the better combination of yield and nutritional traits. The strong positively associated fruit yield traits namely, number of fruits per plant, plant spread in north south, individual fruit weight, stem girth, plant spread in east west, fruit length and plant height with fruit yield per plant contributed for higher green chilli yields. So, the high yielding ability of the genotypes could be explained due to the better combination of these positively associated traits, which are also easily measurable and thus could be considered as principal yield determinant traits to score large number of plants in chilli yield selection programs.

Future Scope
Associations among the yield and yield attributing traits as well as fruit quality traits in the desirable direction need to be considered in selection schemes for yield and quality improvement in chilli.

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Conflict of interest: None

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