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PLANT BREEDING | ORIGINAL ARTICLE

Genetic variability and correlation analysis based on yield and yield related traits in chilli (*Capsicum annuum* L.)

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ABSTRACT

A field experiment was conducted in the field laboratory of the Department of Genetics and Plant Breeding, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, during the period from October 2018 to April 2019, to determine the genetic variability and correlation for yield and yield attributing traits of twenty-eight chilli (*Capsicum annuum* L.) genotypes. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Seeds of the selected chilli genotypes were collected from different sources and were raised in polybags and then transplanted to the experimental plot. The experiment was laid out in a randomized complete block design with three replications. Data on yield and yield related traits were recorded at the respective stage of the crop. Among the studied genotypes, the fruit length (FRLN) varied 1 cm to 16.3 cm with an average length of 6.5 cm. The lowest fruit diameter (FRDM) was 3.3 mm and the highest was 15.1 mm. The fruit yield ranged between 0.018 and 1.044 kg/plant. The lowest fruit weight was recorded 0.3 g, while the highest fruit weight was 6.3 g. The highest significant genotypic and phenotypic variance was found in number of fruits/plant and genotypic co-efficient of variation and phenotypic co-efficient of variation were found highest in fruit yield/plant (FYPP). High heritability coupled with high genetic advance was found in number of fruits/plant which indicates that the heritability is due to additive gene effects and the selection might be very effective in chilli breeding. Among the agronomic parameters, FYPP was significantly correlated with individual fruit weight and the amount of seeds/plant. It was also found that the height of chilli plant positively influenced the amount of fruits/plant. However, plant height negatively affected fruit diameter and number of fruits per plant. The results of the present study suggests that there is a great genetic potential in the studied genotypes. This study did not use molecular markers to assess genetic diversity; instead, it focused on a single location during a single season. Therefore, repeated genotype evaluation across multiple locations is recommended in order to assess the genetic diversity of genotype types based on molecular markers.

1. Introduction

Chilli (*Capsicum annuum* L.) originated in South and Central America belongs to the family Solanaceae is a spice crop and also used as vegetable and widely cultivated throughout the world (Dias et al., 2013; Wahyuni et al., 2012). The constituents of chilli are important for its nutritional value, aroma, texture, color and it is also a good source of oleoresin which has diversified uses in process food, beverage industries and in pharmaceuticals (Marín et al., 2004; Osuna-García et al., 1998). It is rich in proteins, lipids, carbohydrates, fibres, mineral salts (Ca, P, Fe) and in vitamins A, D, E, C, K, B2 and B12 (El-Ghorab et al., 2013). It is sometimes referred as capsule of vitamin C because of rich vitamin C content in the fruit (Durust et al., 1997). It is mainly used for its pungency and pleasant flavor. Chilli, of the genus *Capsicum*, has more than 25 commonly used species with four cultivars groups as Chinese group (West Indies chilli), Frutescens group (bird chilli), Annuum group (hot chilli) and sweet pepper group (Nsabiyera et al., 2013). Throughout the world, chilli is generally consumed either in fresh, dried or in powder (El-Ghorab et al., 2013).

Crop improvement in chilli has so far been achieved by exploiting the available sources of the variability. Naturally, the genetic variation or diversity for most of the yield attributes is considerably high in chilli. There is a need to seek improvement in complex quantitative trait such as yield. As a result of free exchange of chilli germplasm and lot of introgressions of characters has taken place in many local chilli cultivars resulting in

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enhancement of variability and new genetic combinations. Since yield is a complex trait, governed by a large number of contributing traits. It is imperative to know the interrelationship between yield and its contributing traits to achieve at an optimal selection index for improvement of yield (Saisupriya et al., 2020). For efficient and effective breeding work, investigation and better understanding of the variability existing in a population base of crop is also required so that it can be exploited by plant breeder for crop improvement. Moreover, the success of any crops improvement program depends not only on the amount of genetic variation present in a crop but also on magnitude of variation which is heritable from the parent to the progeny (Bello et al., 2012). The critical assessment of nature and magnitude of variability in the germplasm stock is one of the important pre-requisites for formulating effective breeding methods (Krishna et al., 2007). The choice of the most suitable breeding method for the rational improvement of yield and its components in any crop largely depends upon the genetic variability, correlations and association between qualitative and quantitative characters and heritability estimates. Therefore, the present study was conducted to determine the genetic variability of selected chilli genotypes as wellas to assess the correlation among yield and yield attributing traits.

2. Materials and Methods

2.1.1. Experimental site

The study was conducted 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 location of the experimental site was at the center of Madhupur Tract (24.05° N latitude and 90.25° E longitude, AEZ-28) with an elevation of 8.4 meters from the sea level. The pH of the soil in the experimental field was 5.5 and the texture was clay loam. The climate of the experimental site is subtropical in nature, marked by heavy rainfall from June to September and sparse water with a steady fall in temperature beginning in September. The weather information for the study period is provided in Figure 1.

2.1.2. Field experimentation procedure

The land was prepared thoroughly by 3-4 times ploughing and cross ploughing followed by laddering. Adequate soil fertility was ensured by applying additional quantities of urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum, zinc sulphate and boric acid @ 270-170-100-150-115-88 kg/ha, respectively. Total TSP, MoP, gypsum, zinc sulphate and boric acid were applied during the final land preparation. Cowdung was also applied @ 10 t/ha during final land preparation.

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The experimental area was divided into three blocks. Twenty-eight chilli genotypes were assigned randomly in each block. The spacing was maintained at 45 cm between rows and 45 cm between plants. One meter distance was kept between the blocks of the replication. A population of twenty plants was maintained per replication per genotype by planting a single plant per hill.

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The transplantation of 28-day seedlings was done on December 28, 2018. Raised beds were prepared for transplanting. One seedling was transplanted per pit and light irrigation was given immediately after transplanting. After one week, gap filling was done whenever the death of previously transplanted seedlings occurred. All other recommended practices were adopted to raise the healthy chilli crop. During the crop cycle, appropriate intercultural operations were performed for proper plant growth and development, such as irrigation of the crop at vegetative and reproductive stages, weeding and soil mulching as and whenever necessary.

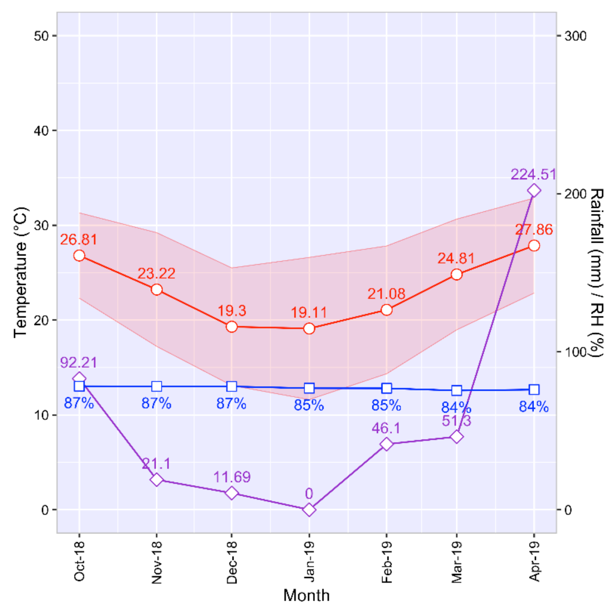

Figure 1. Weather condition of the study location. The upper and lower limits of the ribbon designate the maximum and minimum temperature, respectively. The red, blue and violet line represent average temperature, relative humidity and rainfall, respectively.

The first and second weeding was done 15 and 30 days after transplanting (DAT), respectively, followed by top dressing of urea. Bamboo stalks were used for supporting the fruit bearing plants. Irrigation was given at regular intervals. The recommended dose of urea was applied in three installments, at 15, 30 and 50 days after transplanting (DAT).

Different types of insect pests were faced during the experimental period such as mites, aphids and thrips. The spraying of Tiddo 20 SL @ 2.5 mL/10L along with Vertimec 18 EC @ 1.2 mL/L were done against the attack of mites and thrips after 10 days of transplanting to one month before harvesting at 3-days interval. Drenching with Regent powder @ 10 mL/L was done to control incidence of thrips attack.

2.1.3. Data collection

Five plants were selected randomly from each genotype and selected plants were marked by labeling for recording data on yield and yield related parameters. Data on days to 50% flowering (DFTF), days to 50% fruit setting (DFTS), days to 50% green fruit maturity (DFTM), were recorded before fruit harvesting. Data on fruit length (FRLN), fruit diameter (FRDM), number of fruits per plant (FRPP), individual fruit weight (IFRW), number of seeds per fruit (NSPF) and fruit yield per plant (FYPP) were recorded after harvesting. Green fruits were harvested when they were relatively firm and crispy. Harvesting of fruits was done three times in each replication. Plant height was recorded during the final harvest.

2.1.4. Data analysis and visualization

Analysis of variance (ANOVA), mean, and coefficient of variation (CV) were done from the replicated data of yield and yield related parameters by using the open-source statistical platform 'R' (version 4.02) (R Core Team, 2021). Genotypic and phenotypic variance was estimated by the formula used by Johnson et al. (1955). Heritability in broad sense (h^2b), genetic advance (GA) and genetic advance in percentage of mean (GA%) were measured using the formula given by Singh and Chaudhury (1985). Both genotypic and phenotypic coefficients of variation between two characters were determined by using the variance and covariance components as suggested by Al-Jibouri et al. (1958). The relationships between yield and yield related characters of chilli were assessed using Pearson's correlation co-efficient. 'Hmisc' and 'corrplot' packages of 'R' (version 4.02) (R Core Team, 2021) were used for preparing the correlation matrix.

3. Results and Discussion

The mean performance of the genotypes for yield and yield related traits are shown in Figure 2, whereas the estimated variability components viz. phenotypic and genotypic variance, phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV), heritability in broad sense (h^2b), genetic advance (GA) as percent of means (GA%) for 10 characters are presented in Table 1.

3.1.1. Mean performance for yield and its attributing traits of chilli genotypes

All yield related parameters and yield, except days to 50% flowering, varied significantly (all $p<0.01$) among genotypes. Days to 50% flowering (DFTF) ranged between 30 and 130 days with an average of 114.7 days (Figure 2). The earliest 50% fruit setting (DFTS) was observed in 111 days, whereas the lates was recorded in 139 days. The mean value of DFTS was 125.6 days. Days to 50% green fruit maturity (DFTM) ranged between 146 days and 171 days with an average value of 161.5 days (Figure 2). Among the studied genotypes, the fruit length (FRLN) varied 1 cm to 16.3 cm with an average length of 6.5 cm. The variation of fruit length in the studied genotype is higher than other genotypes reported in Bangladesh (Rahman et al., 2017; Uddin et al., 2015). The lowest fruit diameter (FRDM) was 3.3 mm and the highest was 15.1 mm (Figure 2). The average fruit diameter was found 10.22 mm. Number of fruits/plants (FRPP) and individual fruit weight (IFRW) are yield contributing characters in chilli. FRPP varied between 50 and 226 with an average of 138 fruits/plant (Figure 2). The lowest fruit weight was recorded 0.3 g, while the largest fruit weight was 6.3 g (Figure 2). The average value of IFRW was 2.43 g (Figure 2). Therefore, a wide variation was found in respect of individual fruit among the germplasm. Individual fruit weight in this investigation was found considerably higher than the record of Uddin et al. (2015) in Bangladesh and Manju and Sreelathakumary (2002) in India. The fewest seed producer genotype was found to produce 35.9 seeds/fruit while the prolific seed producer genotype gave 105.9 seeds/fruit (Figure 2). The average value of number of seeds/fruit (NSPF) was 71.57 (Figure 2). There was a wide range of fruit yield/plant (FYPP) among the studied chilli genotypes. Among the studied chilli genotypes, the shortest stature was recorded as 30.10 cm, whereas the tallest plant had a height of 88.1 cm (Figure 2). The average plant height (PLHT) was 53.92 cm. The fruit yield ranged between 0.018 kg/plant and 1.044 kg/plant. The average yield of the genotypes was 0.34 kg/plant (Figure 2) which is higher than the study reported by Rahman et al. (2017) but lower than study reported by Manju and Sreelathakumary (2002) in Indian who reported the yield 51.31- 1649.72 g/plant.

3.1.2. Genetic variability, heritability and genetic gain for yield and its attributing traits of the studied chilli genotypes

All of the studied parameters had higher phenotypic variance than genotypic variance. The highest genotypic variance was estimated in number of fruits per plant (1494.7) followed by number of seeds per fruit (233.03) and plant height (152.06). The rest of the parameters had combatively lower genotypic variance. The highest value of phenotypic variance was observed in number of fruits per plant (2126.2) followed by number of seeds per fruit (326.13) and plant height (178.78). The highest genotypic coefficient of variation (GCV) (63.47) was estimated in fruit yield per plant followed by individual fruit weight (60.75). These parameters also had the highest and second phenotypic coefficient of variation (67.68 and 61.60, respectively). These high GCV values in the studied genotypes suggested that the possibility of improving traits through selection (Takele et al., 2022).

Very high h^2b was observed for some parameters. The highest heritability was found for individual fruit weight (97.25%) followed by 50% green fruit maturity (96.72%) and fruit length (96.72%). Johnson et al. (1955) suggested that heritability estimates along with genetic gain is usually more helpful than the heritability alone for selecting superior individuals. In the present experiment, fair amount of heritability (70.30%) was coupled with high value of genetic advance (66.33) and for genetic advance as percent mean (48.26) in number of fruits per plant. This high result indicated that these characteristics were less affected by environmental factors. It demonstrated that the phenotypes accurately described their genotypes, and that mass selection based on phenotypic performance would be reliable for chilli improvement by increasing the frequency of beneficial alleles via hybridization (Takele et al., 2022).

Genetic advance as percent of mean is categorized as low, moderate, and high which ranges from < 10%), 10–20%, > 20%, respectively (Johnson et al., 1955). In the present study, very high GA% was recorded for individual fruit weight (123.41%), fruit yield per plant (122.62%) and fruit length (86.54) which corroborate the findings of Sarkar et al. (2009) and Choudhary and Samadia (2004). These were in conformity with the reports of Bhagyalakshmi et al. (1990), Varalakshmi and Babu (1991) and Manju and Sreelathakumary (2004), who also reported higher GA% in these traits. Number of fruits/plant exhibited both high GA% and high heritability, suggesting that additive gene effects are the cause of the heritability and that selection may be highly successful in the breeding of chilli. Therefore, this trait is highly desirable. On the other hand, DFTS and DFTM had high heritability and moderate genetic advance. This suggests that both additive and non-additive gene action have an equal influence on their expression.

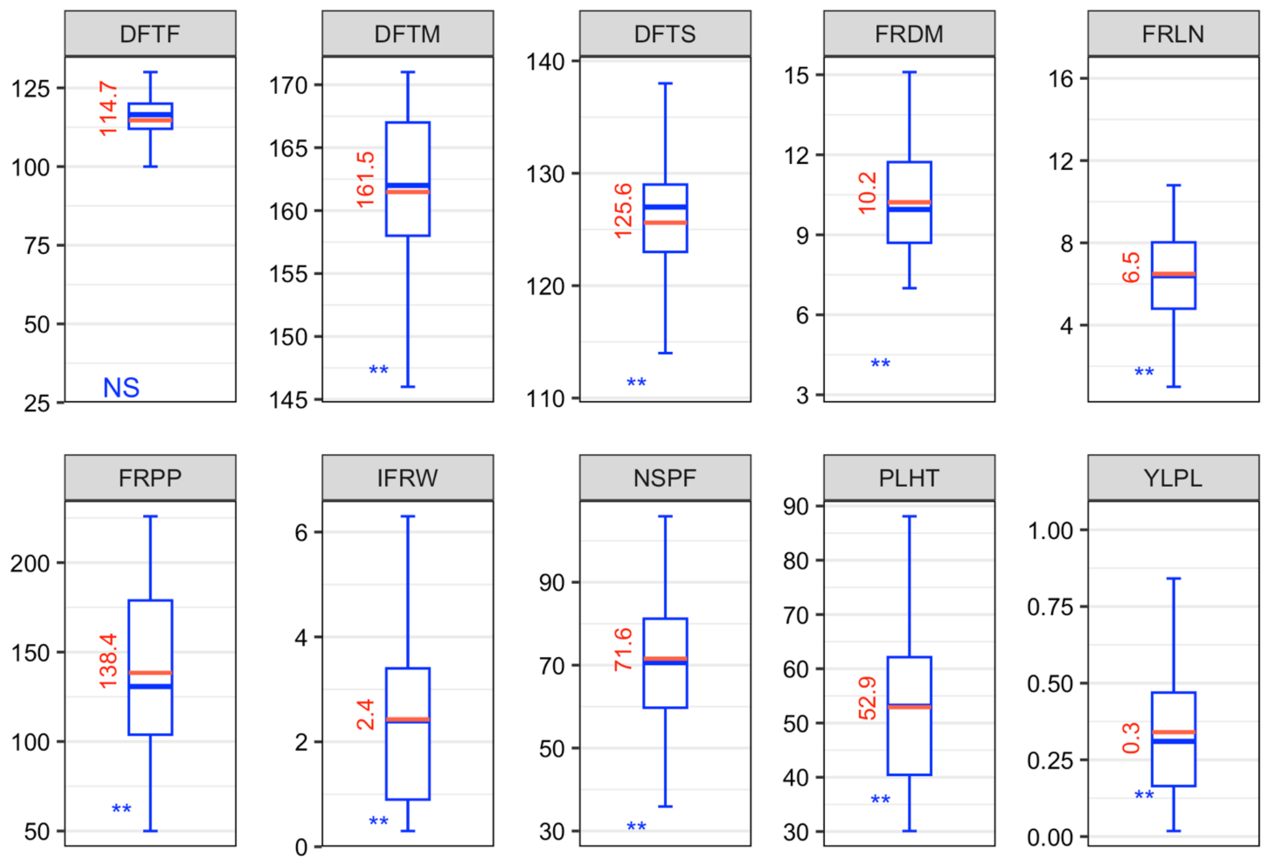

Figure 2. Yield and yield related traits of the studied chilli genotypes. DFTF: days to 50% flowering, DFTS: days to 50% fruiting, DFTM: days to 50% green fruit maturity, DHFM: days to 100% green fruit maturity, FRLN: fruit length (cm), FRDM: fruit diameter (mm), FRPP: number of fruits/plants, IFRW: individual fruit weight (g), NSPF: numbers of seeds/fruit, FYPP: fruit yield/plant (kg), PLHT: plant height (cm). ** indicate that the genotypes are significantly different at 1% level of significance; NS = not significant

Table 1. Genetic variability parameters for yield and yield related characters of chilli

	DFTF	DFTS	DFTM	FRLN	FRDM	FRPP	IFRW	NSPF	FYPP	PLHT
GenVar	12.54	34.78	41.91	7.93	3.05	1494.7	2.17	233.03	0.05	152.06
PhenVar	132.49	37.80	43.33	8.45	4.58	2126.2	2.24	326.13	0.05	178.78
GCV	3.09	4.70	4.01	43.37	17.10	27.94	60.75	21.33	63.47	23.30
PCV	10.03	4.89	4.08	44.78	20.95	33.33	61.60	25.23	67.68	25.27
h^2b	9.47	92.02	96.72	93.82	66.63	70.30	97.25	71.45	87.96	85.05
GA	2.24	11.65	13.11	5.62	2.94	66.77	3.00	26.58	0.42	23.43
GA%	1.96	9.28	8.12	86.54	28.75	48.26	123.41	37.14	122.62	44.27

GenMS: genotypic mean sum squre, min: minimum, max: maximum, CV: co-efficient of variation, GenVar: genotypic variance, PhenVar: phenotypic variance, GCV: genotypic co-efficient of variation (%), PCV: phenotypic co-efficient of variation (%), h^2b: heritability in broad sense (%), GA: genetic advance, GA%: genetic advance as percent mean; DFTF: days to 50% flowering, DFTS: days to 50% fruiting, DFTM: days to 50% green fruit maturity, DHFM: days to 100% green fruit maturity, FRLN: fruit length (cm), FRDM: fruit diameter (mm), FRPP: number of fruits/plant, IFRW: individual fruit weight (g), NSPF: numbers of seeds/fruit, FYPP: fruit yield/plant (kg), PLHT: plant height (cm)

3.1.3. Correlation among yield and yield contributing traits

In parent selection, the goal is often to select plants that exhibit positive correlations among these traits. For example, selecting plants with higher fruit yield per plant, larger fruit size, quicker maturity, and optimal plant height can lead to improved overall productivity and quality in chili production. Conversely, traits that show negative correlations, such as excessive plant height reducing fruit yield or longer maturity periods delaying harvest, may be less desirable unless balanced by other advantageous traits. Fruit yield is the outcome of many mutually dependent traits. As shown in the correlation matrix among the yield and yield related parameters of chilli (Figure 3), fruit yield per plant was significant positive association with individual fruit weight (0.90) and number of seeds per fruit (0.80). This indicates that as the weight of each fruit increases, the overall yield per plant also tends to increase and higher seed count per fruit tends to contribute positively to the total yield per plant. Other researchers (Gupta et al., 2009; Lata & Sharma, 2022; Ullah et al., 2011) also reported that fruit yield per plant was influenced by individual fruit weight. Number of fruits per plant was found to have significant positive correlation (0.82) with the height of chilli plant. Therefore, taller plants tend to bear more fruits per plant. This result is in agreement with Kumar et al. (2012) who reported that taller chilli plants produced higher number of branches and gave higher fruit yield than short statured plants. Fruit diameter had positive correlation with individual fruit weight (0.78) and number of seeds per fruit (0.76). It indicates that larger fruit diameter is associated with heavier fruits and larger fruits may accommodate more seeds (Haque et al., 2020; Quresh et al., 2021). Days to 50% green fruit maturity showed fair positive association days to 50% flowering and very strong positive association with 50% fruit setting (0.96). On the other hand, fruit length had negative correlation with days to 50% fruit setting (-0.76) and days to 50% green fruit maturity (-0.75). This result suggests that longer fruits take less time to set and mature which supports the result of Dayal et al. (2023) who reported that genotype with larger fruit size showed negative correlation with days to fruit setting. Fruit diameter was negatively associated with number of fruits per plant (-0.74) and plant height (-0.7). Similar to fruit length, number of seeds per fruit was negatively correlated with days to 50% fruit setting (-0.85) and days to 50% green fruit maturity (-0.78). These correlations provide valuable insights for understanding how different factors such as fruit size, plant height, and developmental stages (flowering, fruit setting, maturity) interact and influence the overall yield and quality of chili plants. The current study found that each studied trait was associated negatively and favorably, indicating that the traits under consideration were influenced and supported by one another.

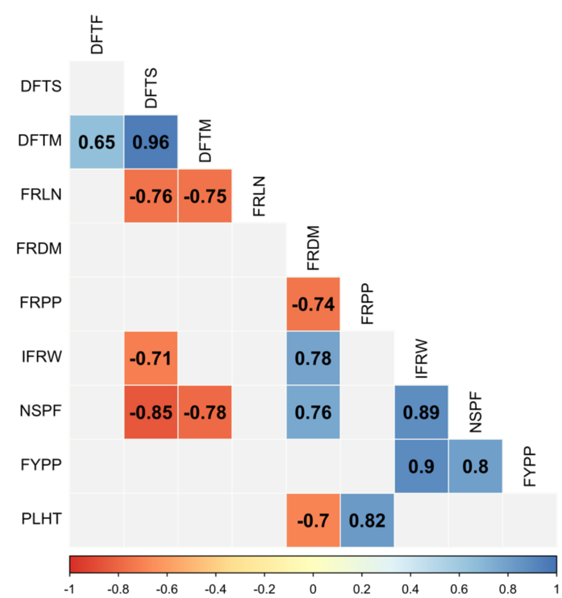

Figure 3. Correlation matrix showing the Pearson's correlation co-efficient (r) between yield and yield related parameters of 28 chilli genotypes. Negative correlations are shown in red color and positive correlations are presented in blue. The color intensity is relative to the value of the correlation coefficients (r). Correlations with non-significant co-efficient values have been dropped out from the matrices.

4. Conclusion

Based on the above discussion most of the qualitative characters showed distinct variation among the studied genotypes. The maximum variation (both genotypic and phenotypic co-efficient) was observed in the number of fruits/plant. The present finding shows the great genetic potential of the studied genotypes. Moreover, the variability observed in the current study could be used in chilli improvement program. However, this study only looked at one place over one season and did not use molecular markers to determine genetic diversity. To evaluate the genetic variety of genotype types based on molecular markers, repeated genotype evaluation across many places is recommended.

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Conflict of Interests

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

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