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# Growth and yield of elite genotypes of chilli (*Capsicum annuum* L.) in diverse agroclimatic zones of Punjab

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## Abstract

Eleven elite genotypes of chilli along with one check (*Punjab Surkh*) were evaluated at two diverse locations of Punjab, India. The G × E interaction was significant for red ripe fruit yield, fruit width and fruit weight and genotype Acc-33-1 was the most stable across locations. The pooled analysis showed that the genotype, SD 463 had the maximum red ripe fruit yield (0.586 kg plant$^{-1}$) and fruit weight (4.1 g); *Mehma Sarja* had the highest plant height (93.5 cm) and fruit width (13.4 mm); Selection 7 exhibited the lowest plant height (37.6 cm) and fruit width (7.0 mm); PC-6-1 had the longest fruits (8.6 cm); DCL 524 possessed maximum number of seeds fruit$^{-1}$ (43.5); Selection 36-1 produced the maximum seed weight (0.211 g fruit$^{-1}$). The low broad sense heritability ($h^2$) for number of seeds fruit$^{-1}$ and dried seed weight fruit$^{-1}$ revealed that these traits were highly influenced by environment. High heritability coupled with high genetic advance for red ripe fruit yield, fruit weight, plant height, fruit length and fruit width indicated the important role played by additive gene effects.

**Keywords:** chilli, G × E interaction, genetic advance, heritability, variability

## Introduction

Chilli (*Capsicum annuum* L.) is one of the most important vegetable-cum-spice crops of India, the largest producer, consumer and exporter of chillies in the world. In India, it was cultivated over 0.869 million hectare in 2010 producing 1.445 million tonnes of dry chillies and peppers with an average productivity of 1.663 tonnes ha$^{-1}$. India contributes about 40% of the total world production and is at the top in terms of international trade, exporting 17% of its total production (FAO 2013). In Punjab, the crop was cultivated over 10,562 ha in 2011–12 producing 17,979 t with an average productivity (1.70 t ha$^{-1}$) which is higher than national average. Chilli production in India is largely taken by the locally available genotypes or open pollinated varieties. The private sector concentrates on the development of $F_1$ hybrids whereas the public sector is concerned with the development of both open-pollinated varieties and $F_1$ hybrids. A few open-pollinated varieties of chilli including *Punjab Surkh* and *Punjab Guchhedar* have been released for commercial

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cultivation by the Punjab Agricultural University (PAU) in 1990's. *Punjab Surkh* is a dual purpose variety which is suitable for green as well as red purpose (Hundal *et al*. 1995a) whereas *Punjab Guchhedar* is suitable for preparing chilli paste due to its high colouring matter and pungency (Hundal *et al*. 1995b). These varieties became quite popular with the farmers. However, with the passage of time, there has been a consistent demand of farmers for new high yielding open-pollinated varieties of chilli suitable for salad, pickle and processing purposes. Therefore, the present study was conducted to identify the promising genotypes of chilli which perform well across locations and can be considered for release as potential varieties and to assess the genetic variability, heritability and genetic advance for various traits in respect of these genotypes for their use in further crop improvement programmes.

**Materials and methods**

The present investigations were conducted at Vegetable Research Farm, Punjab Agricultural University, Ludhiana ($E_1$) (30° 54′ N, 75° 48′ E, 247 m above MSL) and Regional Research Station, Punjab Agricultural University, Bathinda ($E_2$) (30° 13′ N, 74° 57′ E, 201 m above MSL) during October 2010 to September 2011. On the basis of climatic classification based on rainfall, the city of Ludhiana falls in sub-humid zone having an average annual rainfall of 885 mm whereas Bathinda lies in semi-arid zone having an average annual rainfall of 410 mm (Mahi & Kingra 2011). The mean monthly agrometeorological observations were recorded during the crop season at both the locations. Eleven elite genotypes of chilli along with one standard check, *viz*., *Punjab Surkh*, were sown in finely prepared nursery beds in end-October, 2010. The seedlings were transplanted on ridges at a spacing of 60 cm × 45 cm in last week of February, 2011. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Fourteen plants of each entry were maintained in each replication. Recommended cultural and plant-protection measures were followed to raise the crop (Anonymous 2010). The irrigation was applied as per need and at regular intervals at Ludhiana, however, at Bathinda, irrigation was not applied for three weeks in April, though needed by the crop, due to non-availability of good quality canal water, and tubewell water being saline was not used for irrigation purpose. The observations were recorded for seven characters, *viz*., red ripe fruit yield (kg plant$^{-1}$), plant height (cm), fruit length (cm), fruit width (mm), fruit weight (g), number of seeds fruit$^{-1}$ and dried seed weight (g fruit$^{-1}$). Plant height was recorded at final picking on five randomly chosen competitive plants. Fruit length and fruit width were recorded on five randomly selected fruits from fourth picking. Ten fruits taken from fourth picking were dried at room temperature and seed was hand extracted, counted and weighed to estimate number of seeds fruit$^{-1}$ and dried seed weight (g fruit$^{-1}$). The data were analyzed for analysis of variance using the software CPCS1. The genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) (Johnson *et al*. 1955), phenotypic correlation coefficient (Al-Jibouri *et al*. 1958), heritability in broad sense ($h^2$) and genetic advance as per cent of mean at 5% intensity of selection (Burton & Devane *et al*. 1953) were calculated using the software MVM.

**Results and discussion**

At Bathinda ($E_2$), the mean monthly maximum air temperature was higher from March to September by 0.3-3.8°C while the minimum was lower by 0.3-1.1°C than at Ludhiana ($E_1$). At Ludhiana ($E_1$), the mean monthly morning relative humidity was higher for five out of eight months by 0.5-11% while evening relative humidity for seven months by 7.4-19% as compared to that at Bathinda ($E_2$). The total monthly rainfall was higher at Ludhiana ($E_1$) than at Bathinda ($E_2$) during all the months except July and September, however, the total rainfall at Ludhiana during these eight months (1269.7 mm) was considerably higher than at Bathinda (502.4 mm). The total evaporation at Ludhiana ($E_1$) was higher during February, March and September, and lower during April to August than at Bathinda ($E_2$). This data shows considerable variation in the climate of the two locations.

The mean sum of squares due to genotype were significant in both the environments for all the traits except for dried seed weight in $E_2$ (Table 1) revealing the presence of genotypic variability for the traits studied. The pooled analysis (Table 1) showed that the mean squares due to environment were significant for all the traits except plant height signifying the important role played by environment in the expression of these traits. The G × E interaction was found to be significant for three traits, *viz*., fruit yield, fruit width and fruit weight which meant that the performance of the genotypes for these traits was significantly different in both the environments whereas for other traits the performance of the genotypes was on a par at both the locations. While evaluating 14 cultivars of hot pepper at two elevations of Thailand, Gurung *et al*. (2011) have reported significant G × E interaction for yield, fruit weight and fruit width and non-significant interaction for fruit length.

High yield is one of the most important objectives in any crop improvement programme. The maximum pooled red ripe fruit yield was exhibited by SD 463 (0.586 kg plant$^{-1}$) which was 304.1% higher than check, *viz*., *Punjab Surkh* (0.145 kg plant$^{-1}$) and was significantly higher than that of VR-16 (0.440 kg plant$^{-1}$), Acc-33-1 (0.437 kg plant$^{-1}$) and C-31-1 (0.435 kg plant$^{-1}$) (Table 2). However, due to the presence of G × E interaction for this trait, the results with respect to locations differed significantly; SD 463 and VR-16 outyielded other genotypes at Ludhiana and Bathinda, respectively (Table 2).

Plant height is an important growth parameter from crop management point of view. The genotype *Mehma Sarja* had the tallest plants in both the environments. The pooled analysis showed that the plant height of *Mehma Sarja* (93.5 cm) was significantly higher than that of Selection 1-1 (80.2 cm) and PC-6-1 (74.2 cm) (Table 2). On the other hand, the genotype Selection 7 had the lowest plant height (37.6 cm) (Table 2). The genotypes having maximum and minimum plant height were not highest or lowest yielding, respectively, revealing the absence of correlation of plant height with red ripe fruit yield (Table 4) corroborating the

**Table 1.** Analysis of variance for seven traits in 12 genotypes of chilli evaluated at two locations

| Source of variation | df | Red fruit yield(kg plant$^{-1}$) | Plant height(cm) | Fruit length(cm) | Fruit width(mm) | Fruit weight(g) | No. of seeds fruit$^{-1}$ | Dried seed weight (g fruit$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| | | | | | $E_1$ | | | |
| Replication | 2 | 0.036* | 5.539 | 0.029 | 0.006 | 0.267* | 4.199 | 0.00006 |
| Genotype | 11 | 0.067* | 708.182* | 7.241* | 12.680* | 4.071* | 297.727* | 0.01048* |
| Error | 22 | 0.002 | 17.597 | 0.137 | 0.194 | 0.069 | 55.146 | 0.00213 |
| | | | | | $E_2$ | | | |
| Replication | 2 | 0.005 | 2.750 | 0.383 | 0.351 | 0.290* | 94.180 | 0.00561 |
| Genotype | 11 | 0.061* | 623.762* | 5.105* | 11.577* | 2.103* | 169.731* | 0.00424 |
| Error | 22 | 0.009 | 32.834 | 0.624 | 0.462 | 0.081 | 71.291 | 0.00217 |
| | | | | | Pooled | | | |
| Replication (within environment) | 4 | 0.020* | 4.144 | 0.206 | 0.179 | 0.279* | 49.189 | 0.003 |
| Environment (E) | 1 | 0.088* | 9.437 | 41.132* | 13.869* | 14.760* | 2005.555* | 0.096* |
| Genotype (G) | 11 | 0.098* | 1282.511* | 11.829* | 22.624* | 5.777* | 402.933* | 0.012* |
| Interaction (G × E) | 11 | 0.030* | 49.434 | 0.519 | 1.633* | 0.397* | 64.525 | 0.002 |
| Error | 44 | 0.005 | 25.215 | 0.380 | 0.328 | 0.075 | 63.219 | 0.002 |

*P<0.05

**Table 2.** Mean performance of 12 accessions of chilli evaluated at two locations for seven traits

| Genotype | Red fruit yield (kg $plant^{-1}$) | | | Plant height (cm) | | | Fruit length (cm) | | |
|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ | $E_2$ | Pooled | $E_1$ | $E_2$ | Pooled | $E_1$ | $E_2$ | Pooled |
| PC-6-1 | 0.357 | 0.380 | 0.368 | 68.9 | 79.6 | 74.2 | 9.5 | 7.7 | 8.6 |
| Selection 1-1 | 0.208 | 0.165 | 0.186 | 85.0 | 75.4 | 80.2 | 5.5 | 4.8 | 5.1 |
| VR-16 | 0.364 | 0.517 | 0.440 | 65.8 | 69.1 | 67.4 | 6.7 | 5.3 | 6.0 |
| DCL-524 | 0.500 | 0.277 | 0.388 | 49.5 | 50.3 | 49.9 | 6.3 | 4.8 | 5.5 |
| C-31-1 | 0.485 | 0.386 | 0.435 | 65.2 | 69.3 | 67.2 | 8.8 | 7.2 | 8.0 |
| Acc-33-1 | 0.428 | 0.446 | 0.437 | 52.5 | 52.9 | 52.7 | 7.7 | 7.1 | 7.4 |
| SD 463 | 0.746 | 0.427 | 0.586 | 66.2 | 67.3 | 66.7 | 7.9 | 6.2 | 7.0 |
| Selection 20 | 0.355 | 0.075 | 0.215 | 72.7 | 64.8 | 68.7 | 8.7 | 5.9 | 7.3 |
| *Mehma Sarja* | 0.295 | 0.298 | 0.296 | 95.0 | 92.0 | 93.5 | 7.0 | 5.7 | 6.3 |
| Selection 7 | 0.259 | 0.263 | 0.261 | 38.5 | 36.7 | 37.6 | 6.9 | 5.3 | 6.1 |
| Selection 36-1 | 0.359 | 0.397 | 0.378 | 70.0 | 70.8 | 70.4 | 8.6 | 6.8 | 7.7 |
| *Punjab Surkh* (Check) | 0.204 | 0.087 | 0.145 | 77.5 | 69.9 | 73.7 | 4.1 | 3.0 | 3.5 |
| Mean | 0.380 | 0.310 | 0.345 | 67.2 | 66.5 | 66.8 | 7.3 | 5.8 | 6.5 |
| CV (%) | 12.40 | 30.40 | 21.60 | 6.24 | 8.62 | 7.51 | 5.05 | 13.59 | 9.39 |
| CD (G) ($P<0.05$) | 0.080 | 0.160 | 0.087 | 7.1 | 9.7 | 5.8 | 0.6 | 1.3 | 0.7 |
| CD (E) ($P<0.05$) | | | 0.035 | | | NS | | | 0.3 |
| CD (G × E) ($P<0.05$) | | | 0.122 | | | 8.3 | | | 1.0 |

**Table 2.** *Contd.*

| Genotype | Fruit width (mm) | | | Fruit weight (g) | | | No. of seeds fruit$^{-1}$ | | | Dried seed weight (g fruit$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ | $E_2$ | Pooled | $E_1$ | $E_2$ | Pooled | $E_1$ | $E_2$ | Pooled | $E_1$ | $E_2$ | Pooled |
| PC-6-1 | 9.2 | 9.3 | 9.2 | 3.4 | 1.9 | 2.7 | 26.7 | 13.3 | 20.0 | 0.094 | 0.052 | 0.073 |
| Selection 1-1 | 7.2 | 10.5 | 8.8 | 1.6 | 1.6 | 1.6 | 24.4 | 19.9 | 22.1 | 0.105 | 0.095 | 0.100 |
| VR-16 | 8.0 | 9.9 | 8.9 | 2.3 | 1.6 | 1.9 | 37.0 | 18.1 | 27.5 | 0.143 | 0.071 | 0.107 |
| DCL-524 | 9.0 | 9.6 | 9.3 | 2.0 | 1.5 | 1.8 | 49.9 | 37.2 | 43.5 | 0.218 | 0.112 | 0.165 |
| C-31-1 | 10.8 | 12.7 | 11.7 | 4.6 | 3.5 | 4.0 | 48.7 | 31.2 | 39.9 | 0.261 | 0.136 | 0.198 |
| Acc-33-1 | 9.8 | 9.9 | 9.8 | 2.9 | 2.5 | 2.7 | 37.8 | 32.2 | 35.0 | 0.228 | 0.162 | 0.195 |
| SD 463 | 12.8 | 12.7 | 12.7 | 5.0 | 3.2 | 4.1 | 44.3 | 24.5 | 34.4 | 0.226 | 0.134 | 0.180 |
| Selection 20 | 9.1 | 9.6 | 9.3 | 2.8 | 1.9 | 2.3 | 21.4 | 15.9 | 18.6 | 0.127 | 0.065 | 0.096 |
| *Mehma Sarja* | 12.6 | 14.2 | 13.4 | 3.9 | 3.3 | 3.6 | 27.2 | 28.1 | 27.6 | 0.150 | 0.145 | 0.147 |
| Selection 7 | 6.8 | 7.3 | 7.0 | 1.8 | 1.2 | 1.5 | 48.2 | 33.4 | 40.8 | 0.204 | 0.108 | 0.156 |
| Selection 36-1 | 12.3 | 12.8 | 12.5 | 4.3 | 2.7 | 3.5 | 35.8 | 29.2 | 32.5 | 0.255 | 0.168 | 0.211 |
| *Punjab Surkh* (Check) | 11.2 | 11.1 | 11.1 | 2.1 | 1.3 | 1.7 | 33.9 | 25.6 | 29.7 | 0.227 | 0.113 | 0.170 |
| Mean | 9.9 | 10.8 | 10.3 | 3.1 | 2.2 | 2.6 | 36.3 | 25.7 | 31.0 | 0.190 | 0.110 | 0.150 |
| CV (%) | 4.45 | 6.30 | 5.53 | 8.53 | 13.07 | 10.42 | 20.47 | 32.83 | 25.65 | 24.77 | 41.12 | 30.95 |
| CD (G) (P<0.05) | 0.7 | 1.1 | 0.7 | 0.4 | 0.5 | 0.3 | 12.6 | 14.3 | 9.2 | 0.078 | NS | 0.054 |
| CD (E) (P<0.05) | | | 0.3 | | | 0.1 | | | 3.8 | | | 0.022 |
| CD (GXE) (P<0.05) | | | 0.9 | | | 0.4 | | | 13.1 | | | 0.076 |

address: CV = Coefficent of variation; NS = Non-significant finding of Tembhurne *et al*. (2008). However, plant height and fruit yield have been reported to have significant positive correlation (Kumari *et al.* 2011) and significant negative correlation (Gupta *et al*. 2009). These differences may be due to the differences in the genotypes included in the study.

Fruit length and fruit width are important yield contributing characters that also decide consumer acceptability. The genotype PC-6-1 had the longest fruits at both the locations. The pooled fruit length of PC-6-1 (8.6 cm) was, however, on par with C-31-1 (8.0 cm) and was 145.7% higher than *Punjab Surkh* (3.5 cm), the genotype having minimum fruit length (Table 2). The pooled analysis showed that the maximum fruit width was exhibited by *Mehma Sarja* (13.4 mm) which was at par with SD 463 (12.7 mm) whereas the minimum fruit width was recorded by Selection 7 (7.0 mm) (Table 2). However, owing to the presence of G × E interaction for this trait, the results with respect to locations differed significantly, SD 463 produced the maximum fruit width (12.8 mm) at Ludhiana which was at par with *Mehma Sarja* (12.6 mm) and Selection 36-1 (12.3 mm), whereas at Bathinda, the genotype *Mehma Sarja* produced maximum fruit width (14.2 mm) which was significantly higher than all other genotypes (Table 2). Fruit length and fruit width were positively correlated with red ripe fruit yield (Table 4). Positive association of fruit length with fruit yield has also been reported by Tembhurne *et al*. (2008), Gupta *et al*. (2009) and Kumari *et al*. (2011).

Fruit weight contributes towards total yield and has a key role in acceptance of produce by the consumer. The pooled analysis showed that the genotype SD 463 produced the heaviest fruits (4.1 g) which was at par with C-31-1 (4.0 g) and 141.2% higher than check, *viz*., *Punjab Surkh* (1.7 g) (Table 2). However, due to the presence of G × E interaction for this trait, the results with respect to locations differed significantly, SD 463 produced heaviest fruits (5.0 g) at Ludhiana which was at par with C-31-1 (4.6 g) whereas at Bathinda, the genotype C-31-1 produced the heaviest fruits (3.5 g)

**Table 3.** Genetic variability parameters, heritability and genetic advance for seven traits in 12 genotypes of chilli evaluated at two locations

| Trait | Location | Mean ± SE | Range | PCV (%) | GCV (%) | $h^2$ (%) | GA (%) |
|---|---|---|---|---|---|---|---|
| Red fruit yield (kg plant$^{-1}$) | $E_1$ | 0.380 ± 0.027 | 0.204-0.746 | 40.64 | 38.71 | 90.70 | 75.94 |
| | $E_2$ | 0.310 ± 0.054 | 0.075-0.517 | 52.20 | 42.44 | 66.08 | 71.06 |
| Plant height (cm) | $E_1$ | 67.2 ± 2.4 | 38.5-95.0 | 23.41 | 22.57 | 92.90 | 44.80 |
| | $E_2$ | 66.5 ± 3.3 | 36.7-92.0 | 22.79 | 21.10 | 85.71 | 40.24 |
| Fruit length (cm) | $E_1$ | 7.3 ± 0.2 | 4.1-9.5 | 21.61 | 21.01 | 94.55 | 42.08 |
| | $E_2$ | 5.8 ± 0.5 | 3.0-7.7 | 25.03 | 21.02 | 70.53 | 36.37 |
| Fruit width (mm) | $E_1$ | 9.9 ± 0.3 | 6.8-12.8 | 21.05 | 20.58 | 95.53 | 41.43 |
| | $E_2$ | 10.8 ± 0.4 | 7.3-14.2 | 18.92 | 17.84 | 88.92 | 34.65 |
| Fruit weight (g) | $E_1$ | 3.1 ± 0.2 | 1.6-5.0 | 38.44 | 37.49 | 95.08 | 75.30 |
| | $E_2$ | 2.2 ± 0.2 | 1.2-3.5 | 39.94 | 37.74 | 89.28 | 73.46 |
| No. of seeds fruit$^{-1}$ | $E_1$ | 36.3 ± 4.3 | 21.4-49.9 | 32.15 | 24.79 | 59.45 | 39.37 |
| | $E_2$ | 25.7 ± 4.9 | 13.3-37.2 | 39.67 | 22.27 | 31.52 | 25.76 |
| Dried seed weight (g fruit$^{-1}$) | $E_1$ | 0.190 ± 0.027 | 0.094-0.261 | 37.60 | 28.28 | 56.58 | 43.82 |
| | $E_2$ | 0.110 ± 0.027 | 0.052-0.168 | 47.20 | 23.17 | 24.11 | 23.44 |

PCV=Phenotypic coefficient of variation; GCV=Genotypic coefficient of variation; $h^2$=Heritability in broad sense; GA=Genetic advance as per cent of mean

**Table 4.** Phenotypic correlation coefficient ($r_p$) among seven traits in 12 genotypes of chilli evaluated at two locations

| Trait | Location | Red fruit yield (kg plant$^{-1}$) | Plant height (cm) | Fruit length (cm) | Fruit width (mm) | Fruit weight (g) | No. of seeds fruit$^{-1}$ |
|---|---|---|---|---|---|---|---|
| Plant height (cm) | $E_1$ | -0.26 | | | | | |
| | $E_2$ | 0.03 | | | | | |
| Fruit length (cm) | $E_1$ | 0.42* | -0.15 | | | | |
| | $E_2$ | 0.54* | 0.12 | | | | |
| Fruit width (mm) | $E_1$ | 0.42* | 0.41* | 0.20 | | | |
| | $E_2$ | 0.15 | 0.64* | 0.12 | | | |
| Fruit weight (g) | $E_1$ | 0.63* | 0.23 | 0.65* | 0.79* | | |
| | $E_2$ | 0.42* | 0.40* | 0.56* | 0.75* | | |
| No. of seeds fruit$^{-1}$ | $E_1$ | 0.42* | -0.57* | 0.05 | 0.01 | 0.15 | |
| | $E_2$ | 0.05 | -0.42* | -0.02 | 0.15 | 0.15 | |
| Dried seed weight (g fruit$^{-1}$) | $E_1$ | 0.34* | -0.29 | 0.06 | 0.40* | 0.36* | 0.80* |
| | $E_2$ | 0.18 | -0.07 | 0.14 | 0.50* | 0.41* | 0.80* |

Critical value of $r_p$ (5%) at 34 degrees of freedom is 0.33; *denotes significance at $P<0.05$

which was at par with *Mehma Sarja* (3.3 g) and SD 463 (3.2 g) (Table 2). Fruit weight was significantly and positively correlated with red ripe fruit yield (Table 4). This is in contrast to the findings of Tembhurne *et al.* (2008) and Gupta *et al.* (2009) who have reported non-significant association between these two traits.

The less seeded fruits will be soft with poor shelf life and transportability besides adversely affecting pungency. On the basis of pooled analysis, the genotype DCL 524 had the maximum seeded fruits (43.5 seeds fruit$^{-1}$) which was at par with Selection 7 (40.8), C-31-1 (39.9), Acc-33-1 (35.0) and SD 463 (34.4) (Table 2). The genotype Selection 36-1 produced maximum seed weight (0.211 g fruit$^{-1}$) that was at par with C-31-1 (0.198 g fruit$^{-1}$), Acc-33-1 (0.195 g fruit$^{1}$), SD 463 (0.180 g fruit$^{-1}$), *Punjab Surkh* (0.170 g fruit$^{-1}$) and DCL 524 (0.165 g fruit$^{-1}$). The genotype PC-6-1 produced lowest seed yield (0.073 g fruit$^{-1}$) that was at par with Selection 20 (0.096 g), Selection 1-1 (0.100 g fruit$^{-1}$) and VR-16 (0.107 g fruit$^{-1}$) (Table 2).

The red ripe fruit yield (0.380 kg plant$^{-1}$), fruit length (7.3 cm) and fruit weight (3.1 g) at Ludhiana was significantly higher than at Bathinda (0.310 kg plant$^{-1}$, 5.8 cm and 2.2 g) (Table 2). This may be due to significantly higher relative humidity, rainfall and regular irrigation application at Ludhiana than at Bathinda. Reduction in fruit yield, number of fruits plant$^{-1}$, fresh weight of fruit due to low water availability or deficit irrigation has also been reported by Jaimez *et al*. (2000), Antony & Singandhupe (2004) and Dorji *et al*. (2005).

The G × E interaction was significant for red ripe fruit yield, fruit width and fruit weight (Table 1). The genotypes PC-6-1, Selection 1-1, C-31-1, Acc-33-1, *Mehma Sarja*, Selection 7, Selection 36-1 and *Punjab Surkh* showed non-significant differences in fruit yield across locations. Similarly, genotypes PC-6-1, DCL 524, Acc-33-1, SD 463, Selection 20, Selection 7, Selection 36-1 and *Punjab Surkh* exhibited non-significant variation in fruit width across locations. Besides, genotype Selection 1-1, Acc-33-1 exhibited at par values of fruit weight across environments (Table 2). Therefore, for these three characters, genotype Acc-33-1 was the most stable across locations followed by PC-6-1, Selection 1-1, Selection 7, Selection 36-1 and *Punjab Surkh.*

The PCV values were considerably higher than GCV for red ripe fruit yield in $E_2$, number of seeds fruit$^{-1}$ and dried seed weight in $E_1$ and $E_2$ (Table 3) which meant that the apparent variation for these traits was not only due to genotypes but also due to the influence of environment and therefore selection for such traits may sometimes be misleading. For other traits, PCV values were marginally higher than GCV which implied that environment played comparatively less significant role in the expression of these characters. The highest GCV was observed for red ripe fruit yield (38.71% and 42.44%) followed by fruit weight (37.49% and 37.74%). It indicated higher magnitude of genetic variability for these traits, thereby suggesting scope for further improvement. The other characters showed low to moderate values of GCV.

The broad sense heritability ($h^2$) estimates were low for number of seeds fruit$^{-1}$ and dried seed weight (Table 3) which indicated that these characters were highly influenced by environmental effects and therefore genetic improvement through selection would be difficult due to the masking effect of the environment on the genotypic effects. On the other hand, the values of $h^2$ were high for red ripe fruit yield in $E_1$, plant height, fruit length, fruit width and fruit weight in $E_1$ and $E_2$ (Table 3) indicating that these characters were less influenced by the environment. High heritability coupled with high genetic advance for red ripe fruit yield, fruit weight, plant height, fruit length and fruit width indicated the important role played by additive gene effects and therefore these traits may be improved by selection. High heritability coupled with high genetic advance in chilli has also been reported for fruit length (Gogoi & Gautam 2002; Manju & Sreelathakumary 2002; Sreelathakumary & Rajamony 2004; Jyothi *et al*. 2011), fruit yield plant$^{-1}$ (Gogoi & Gautam 2002; Manju & Sreelathakumary 2002; Sreelathakumary & Rajamony 2004; Gupta *et al*. 2009; Kumari *et al*. 2010; Jyothi *et al*. 2011), fruit weight (Manju & Sreelathakumary 2002; Sreelathakumary & Rajamony 2004; Gupta *et al*. 2009; Kumari *et al*. 2010) and plant height (Gogoi & Gautam 2002; Manju & Sreelathakumary 2002; Sreelathakumary & Rajamony 2004). Therefore, hybridization among these genotypes followed by selection in segregating generations for fruit weight, fruit length and fruit width may further improve the yield potential of chilli. Based upon the results of this study, genotypes SD 463 and Acc-33-1 are recommended for adaptive research trials at growers' fields across the state to investigate their adaptability and farmers' perceptions before being considered for commercial release.

## References


Al-Jibouri H A, Miller P A & Robinson H F 1958 Genotypic, phenotypic and environmental variances in an upland cotton cross of interspecific origin. Agron. J. 50: 633–637.

Anonymous 2010 Package of practices for cultivation of vegetable crops, Punjab Agricultural University, Ludhiana, India.

Antony E & Singandhupe R B 2004 Impact of drip and surface irrigation on growth, yield and WUE of capsicum (*Capsicum annuum* L.). Agril. Water Manag. 65: 121–132.

Burton G W & Devane E H 1953 Estimating heritability in tall fescue (*Festuca arundinaceae*) from replicated clonal material. Agron. J. 45: 478–481.

Dorji K, Behboudian M H & Zegbe-Dominguez J A 2005 Water relations, growth, yield and fruit quality of hot pepper under deficit irrigation and partial root zone drying. Scientia Hort. 104: 137–149.

FAO 2013 Food and Agriculture Organization of the United Nations. www.faostat.fao.org Accessed 1 June, 2013.

Gogoi D & Gautam B P 2002 Variability, heritability and genetic advance in chilli (*Capsicum* spp.). Agri. Sci. Digest 22: 102–104.

Gupta A M, Singh D & Kumar A 2009 Genetic variability, genetic advance and correlation in chilli (*Capsicum annuum*). Indian J. Agri. Sci. 79: 221–223.

Gurung T, Techawongstien S, Suriharn B & Techawongstien S 2011 Growth, yield and capsaicinoid contents of 14 cultivars of hot pepper (*Capsicum* spp.) at two elevations of Thailand. SABRAO J. Breed. Genet. 43: 130–143.

Hundal J S, Khurana D S & Kaur S 1995a Punjab Surkh -a new high yielding variety of chilli. J. Res. Punjab Agri. Univ. 32: 240.

Hundal J S, Khurana D S & Kaur S 1995b Punjab Guchhedar -a new chilli cultivar for processing. J. Res. Punjab Agri. Univ. 32: 494.

Jaimez R E, Vielma O, Rada F & Garcia-Nunez C 2000 Effects of water deficit on the dynamics of flowering and fruit production in *Capsicum chinense* Jacq. in a tropical semiarid region of Venezuela. J. Agron. Crop Sci. 185: 113–119.

Johnson H W, Robinson H F & Comstock R E 1955 Genotypic and phenotypic correlations in soyabeans and their implications in selection. Agron. J. 47: 477–483.

Jyothi K U, Kumari S S & Ramana C V 2011 Variability studies in chilli (*Capsicum annuum* L.) with reference to yield attributes. J. Hort. Sci. 6: 133–135.

Kumari S S, Jyothi K U, Reddy V C, Srihari D, Sankar A S & Sankar C R 2011 Character association in paprika (*Capsicum annuum* L.). J. Spices Arom. Crops 20: 43–47.

Kumari S S, Jyothi K U, Srihari D, Sankar A S & Sankar C R 2010 Variability and genetic divergence in paprika (*Capsicum annuum* L.). J. Spices Arom. Crops 19: 71–75.

Mahi G S & Kingra P K 2011 Fundamentals of Agrometeorology, Kalyani Publishers, Ludhiana, pp.202–231.

Manju P R & Sreelathakumary I 2002 Genetic variability, heritability and genetic advance in hot chilli (*Capsicum chinense* Jacq.). J. Trop. Agri. 40: 4–6.

Sreelathakumary I & Rajamony L 2004 Variability, heritability and genetic advance in chilli (*Capsicum annuum* L.). J. Trop. Agri. 42: 35–37.

Tembhurne B V, Revanappa & Kuchanur P H 2008 Varietal performance, genetic variability and correlation studies in chilli (*Capsicum annuum* L.). Karnataka J. Agri. Sci. 21: 541–543.