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Genetic variability, heritability and genetic advance studies in chilli (*Capsicum annuum* L.) genotypes

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Abstract
Genetic variability, heritability, genetic advance and genetic advance as a percent over mean for twenty two characters were assessed by field evaluation of sixty chilli genotypes at the Experimental Field, Division of Vegetable Science, SKUAST-K, Shalimar during *Kharif* 2018. The experiment was laid out in randomized complete block design (RCBD) with three replications. High degree of variation was observed for all characters. The difference between phenotypic coefficient of variation and genotypic coefficient were found to be narrow for most of the traits. The high estimates of heritability was found for number of fruits plant^{-1} (99%), fruit length (96%), fruit diameter (68%), fruit weight (95%), number of fruits plant^{-1} (99%), and fruit yield plant^{-1}(99%).

Keywords: Variability, heritability, genetic advance, PCV, GCV

Introduction
Chilli (*Capsicum annuum* L.) (2n=2x=24) belongs to the family *Solanaceae* (Nightshade). The genus name *Capsicum* is derived from the Latin word 'capsa' meaning chest or box because of the shape of fruit which encloses seeds very neatly, as in the box. It is native of Tropical America and West Indies and is believed to have been introduced to India by the Portugese in the seventeenth century. Since then it has gained importance as an inevitable condiment and vegetable. Its production and consumption has steadily increased worldwide during 20th century due to its use as both vegetable and spice and is an important component of diverse cuisines in the world. It is the leading spice-cum-vegetable crop grown commercially throughout the world. Its fruit appear in different shapes, sizes and colours. It is highly valued for its green or red ripe fruits with characteristic pungency, colour and flavour. It is consumed as fresh, dried or in powder form (El-Ghoraba *et al.*, 2013; Pujar *et al.*, 2017) [5, 21]. The fruits are an excellent source of health-related phytochemical compounds, such as vitamin C (143.7µg), vitamin A (292.04 IU) vitamin E (0.69 mg), vitamin K (14 µg) per 100g, minerals like Calcium, Phosphorus and Iron of fruits, alkaloid capsaicin/capsicutin (C_{18} $H_{27}NO_3$) and red pigment Capsanthin ($C_{40}H_{56}0_3$). The crop is grown throughout the world including tropics, subtropics and temperate regions (Pickersgill, 1997) [20]. As per latest statistics it is grown over an area of 791 thousand hectares with an average production of 1888 thousand metric tonnes in India (FOA, 2018) [7]. In Kashmir it is grown on an area of 3,200 hectares with an annual production of 64,800 tonnes (NHB, 2017) [17]. The major chilli growing states of India are Andhra Pradesh, Karnataka, Maharashtra, Orissa, Tamil Nadu, Madhya Pradesh, West Bengal and Rajasthan.

Materials and methods
The present investigation was conducted in the Experimental Field, Division of Vegetable Science, Sher-e-Kashmir University of Agricultural Science & Technology of Kashmir, Shalimar, Srinagar during the year 2018. The experimental field is situated within the premises of university campus, about 12.5 km from main city, at 34° N latitude and 74.9° E longitude. During the experimentation period the average maximum temperature recorded was 25.3°C and the average minimum temperature recorded was 10.9°C. The total precipitation of 800.8

mm was received during 2018. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The experimental material consisted of 60 chilli genotypes. The plot size was kept 2.7x1.4m (3.78m^2). Each plot consisted of 2 rows of each genotype in each replication at spacing of 45 x 45 cm. Observations were recorded on twenty quantitative and qualitative parameters viz., plant height (cm), plant spread (cm), number of branches pant^{-1}, days to flower initiation, days to fruit initiation, days to harvesting, fruit length (cm), fruit diameter (cm), fruit weight plant^{-1} (g), fruit pedicel length (cm), fruit pedicel diameter (cm), number of fruits plant^{-1}, fruit yield plant^{-1}, fruit yield hectare^{-1}, dry matter content (%), vitamin C content (mg/100g), capsaicin content (mg/g), capsanthin content (ASTA units), total phenols (mg/100g) and instrumental colour (L*,a*,b*) to study the magnitude of genetic variability existing in the experimental material under study. Five competitive plants were selected at random from each replication and tagged for recording the biometrical observations.

Genotypic coefficient of variation and phenotypic coefficient of variation were computed by the method of Burton and Devane. Heritability (broad sense) were worked by methods followed by Johnson *et al* and Hanson *et al*. Genetic advance (GA) and genetic advance as a percent over mean (GAM) were worked by following the methods suggested by Lush and Johnson *et al*.

Results and discussion

The analysis of variance was computed to test significant difference among genotypes studied. The mean sum of squares due to various sources for different character are presented in (Table-1). The genotypic and phenotypic coefficient of variability, heritability and genetic advance as percent over mean for each of the characters are presented in (Table-2).

High heritability with high GAM was recorded for most of growth as well as yield characters including., plant height, plant spread, number of branches plant^{-1}, fruit length, fruit weight, number of fruits plant^{-1}, fruit yield plant^{-1}, vitamin C content at green stage, capsaicin content, capsanthin content, days to flower initiation, indicating the predominance of additive gene components in governing these traits. Thus, there is ample scope for improving these characters based on direct selection from the genetic stock studied.

The difference between the genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were found to be narrow for most of the characters. The results suggest that these traits are least affected by environment and selection for these traits on phenotype would be rewarding. For rest of the characters, the estimates of PCV were greater than GCV. This indicates that the variation for these traits is not only by genotypes but also due to environment. Selection based on phenotype may not be rewarding as their expression depends more on environmental factors. Similar observations were reported in chilli by Farhad *et al.* (2008), Patel *et al.* (2009), Gupta *et al.* (2009), Chattopadhyay *et al*. (2011), Zehra (2014), Janaki *et al.* (2015), Pandiyaraj *et al.* (2017) Jogi *et al*. (2017), Ain (2018) [6, 19, 8, 4, 26, 10, 18, 11, 1].

Heritability (b.s.) estimates were high for almost all the characters and ranged from 65 to 100 per cent indicating that the characters were less influenced by environmental effects and the characters are effectively transmitted to the progeny, suggesting major role of genetic constitution in the expression of a character and thus selection based on phenotypic expression could be relied upon. Similar results were observed by Ain (2018) [1]. High heritability was observed for number of fruits plant^{-1}, fruit length, fruit diameter, fruit weight, number of fruits plant, and fruit yield plant^{-1}. This is in accordance with the findings of Smitha and Basavaraja (2006) [25] and Johari and Kumar (2007) [12]; Sarkar *et al.* (2009) [23] for number of fruits plant^{-1}, number of branches plant^{-1}, plant height, length of fruit and fruit yield plant^{-1}, Ibrahim *et al.* (2001) [9]; Rathod *et al.* (2002) [22], Smitha and Basavaraja (2006) [25], Krishna *et al.* (2007) [14], Janaki *et al.* (2015) [10], Chakarbarty *et al.* (2017) [3]for number of fruits plant^{-1} and plant height and Zehra (2014) [26], Ain (2018) [1] for number of fruits plant^{-1}, fruit length, fruit diameter, fruit weight, number of fruits plant, and fruit yield plant^{-1}; Jogi *et al.* (2017) [11] for plant spread. High heritability values for these traits indicates that variation observed was mainly under genetic control and was less influenced by environment.

Among quality characters, high heritability estimates were recorded for vitamin C content, capsaicin content, capsanthin content and total phenol while moderate heritability estimate recorded for fruit diameter. This is consistent with the reports of Ain (2018) [1].

High heritability along with high genetic advance is an important factor for predicting the resultant effect for selecting the best individuals. In the present study, high heritability was accompanied with high values of genetic advance for plant height, plant spread, number of branches plant^{-1}, fruit length, fruit weight, number of fruits plant^{-1}, fruit yield plant^{-1}, vitamin C content at green stage, capsaicin content, capsanthin content, days to flower initiation, indicating the preponderance of additive gene action in control of these traits. This suggests that real progress in improvement of such traits through selection could be realized. These results are in conformity with several workers *viz.*, Smitha and Basavaraja (2006) [25] for days to flower initiation; Johnson *et al*. (1955) [13] and Arya and Saini (1977) [2]; Jogi *et al*. (2017) [11] for number of fruits plant^{-1}, fruit weight, fruit length and fruit yield plant^{-1}; Munshi and Behera (2000) [16]; Manju and Sreelathkumary (2004) [15] for vitamin C and capsaicin content; Chattopadhhyay *et al*. (2011) [4] for vitamin C.

Fruit yield is an important character, which decides the commercial viability of the hybrid/variety. Thus the trait deserves the highest priority in any breeding programme. High heritability along with high genetic gain as per cent of mean for this trait suggested the possibility of selecting high yielding cultivars from the present collection. This was supported by Patel *et al*. 2009 [19]; Sharma *et al*. 2010 [24].

Table 1: Analysis of Variance for various traits in chilli (*Capsicum annuum* L.)

S. No.	Source of variation	d.f	Plant height (cm)	Plant spread (cm)	No. of branches plant^{-1}	Days to flower initiation	Days to fruit initiation	Days to harvesting	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Fruit pedicel length (cm)
1.	Replication	2	8.23	1.94	2.46	0.31	0.05	0.43	0.50	0.01	0.05	0.23
2.	Genotype	59	233.53**	304.79**	223.61**	45.58**	29.81**	393.69**	18.57**	0.11**	11.83**	1.31**
3.	Error	118	1.04	0.80	0.21	0.04	0.03	0.05	0.19	0.01	0.01	0.09

*Significant at 0.05 probability level

**Significant at 0.01 probability level

Table 1: contd…

S. No.	Source of variation	d.f	Fruit pedicel diameter (cm)	No. of fruits plant^{-1}	Fruit yield plant^{-1}(g)	Fruit yield ha^{-1} (q)	Dry matter content (%)	Vitamin C (green) (mg100g^{-1})	Capsaicin content (mg g^{-1})	Capsanthin content (ASTA units)	Total phenol (mg100^{-1}g)	Instrumental Colour L*	Instrumental colour a	Instrumental colour b
1.	Replication	2	0.00	3.27	155.46	1.92	1.34	2.06	0.00	42.81	0.02	2.89	3.20	3.42
2.	Genotype	59	0.00**	11.83**	76217.91**	7822.44**	76.41**	6450.12**	0.03**	778.20**	1.38**	36.64**	31.03**	2.74**
3.	Error	118	0.00	0.01	259.49	1.58	0.07	0.46	0.00	24.62	0.00	0.47	4.55	0.17

*Significant at 0.05 probability level
**Significant at 0.01 probability level

Table 2: Estimates of mean, range, phenotypic variance, genotypic variance, phenotypic and genotypic coefficients of variation for various quantitative and qualitative characters in chilli (*Capsicum annuum* L.)

S. No.	Parameters	Mean	Range	Phenotypic variance (PV)	Genotypic variance (GV)	Phenotypic coefficient of variation (PCV)	Genotypic coefficient of variation (GCV)	H^2 (broad sense)	Genetic gain (Genetic advance as% of mean)
1.	Plant height (cm)	63.83	49.16-86.00	78.53	77.49	13.88	13.79	0.98	28.21
2.	Plant spread (cm)	64.22	44.33-86.64	102.13	101.33	15.73	15.67	0.99	32.15
3.	No. of branches plant^{-1}	34.08	14.26-48.93	74.68	74.46	25.35	25.32	0.99	52.08
4.	Days to flower initiation	34.78	24.40-38.60	15.22	15.18	11.21	11.20	0.99	23.04
5.	Days to fruit initiation	46.05	31.40-46.53	9.96	9.92	7.28	7.27	0.99	14.95
6.	Days to harvesting	117.26	102.40-134.66	131.27	131.212	9.77	9.76	0.99	20.11
7.	Fruit length (g)	12.27	7.00-16.07	6.32	6.12	20.49	20.16	0.96	40.89
8.	Fruit diameter (cm)	1.08	0.78-1.92	0.04	0.03	20.37	16.82	0.68	28.61
9.	Fruit weight (g)	5.13	1.38-9.28	3.95	3.94	38.73	38.67	0.99	79.53
10.	Fruit pedicel length (cm)	4.75	2.10-6.01	0.50	0.40	14.87	13.38	0.80	24.79
11.	Fruit pedicel diameter (cm)	0.28	0.21-0.44	0.00	0.00	15.03	13.40	0.79	24.60
12.	No. of fruits plant^{-1}	54.31	29.66-99.86	291.69	291.13	31.44	31.41	0.99	64.64
13.	Fruit yield/ plant(g)	276.14	59.10-759.52	25578.97	25319.47	57.91	57.62	0.99	118.09
14.	Fruit yield (q hec^{-1})	90.64	23.90-239.43	2608.53	2606.95	56.34	56.32	0.99	115.99
15.	Dry matter content (%)	79.58	61.54-86.07	25.52	25.44	6.34	6.33	0.99	13.03
16.	Vitamin C content at green stage (mg/100g)	133.00	43.86-201.16	2150.34	2149.88	34.86	34.86	0.99	71.80
17.	Capsaicin content (mg/g)	0.53	0.29-0.75	0.01	0.01	20.21	20.04	0.98	40.95
18.	Capsanthin content (ASTA units)	96.03	66.24-125.83	275.821	251.19	17.29	16.50	0.91	32.44
19.	Total phenol(mg/100g)	6.41	4.90-7.70	0.46	0.45	10.63	10.56	0.98	21.59
20.	Instrumental colour L*	41.18	35.22-50.11	12.53	12.05	8.59	8.43	0.96	17.03
21.	Instrumental colour a	36.82	30.78-45.26	13.38	8.82	9.93	8.06	0.65	13.49
22.	Instrumental colour b	15.84	14.34-18.58	1.03	0.85	6.41	5.83	0.82	10.93

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