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Research Note

Genetic variability and trait relationship in green chilli (*Capsicum annuum* L.) under high altitude conditions

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Abstract
An experiment was carried out to determine the genetic variability parameters and character associations in thirty-two chilli genotypes. Based on mean performance, 11 genotypes were observed to be superior for marketable green fruit yield than the standard check varieties 'Him Palam Mirch-2' and DPCH-40-2. High to moderate estimates of PCV and GCV with high heritability coupled with high genetic advance were observed for marketable green fruits/plant, marketable green fruit yield/plant, total green fruits/plant and average green fruit weight. Marketable green fruit yield/plant had positive and significant association with average green fruit weight, marketable green fruits/plant, total green fruits/plant, percent marketable green fruits/plant, ascorbic acid and capsaicin content. In view of direct and indirect contribution of component traits, selection on the basis of total fruits/plant and average green fruit weight would be a paying preposition for evolving high yielding genotypes for marketable green fruit yield. The present findings could be useful in selecting superior genotypes to achieve genetic gain and yield advantage in chilli breeding programmes.

Keywords: Correlation, Genetic variability, Heritability, Mean, Path analysis

Chilli (*Capscium annuum* L.) (2n=24) a significant vegetable cum spice crop in the family Solanaceae, originates from South and Central America. It is widely grown in tropical Asia and equatorial America with an extensive amount of genetic diversity due to its edible and pungent fruit with nutritional values (Herath *et al.,* 2021). With an annual production of 4363 thousand MT from 411 thousand ha, India is the world's top producer, consumer and exporter of green chilli (NHB, 2020-21). The genus *Capsicum* is a source of products that are used as a vegetable, spice, condiment, culinary supplement, medicine, and ornamental plant all over the world. Chilli fruit contains a wide range of antioxidants, vitamins especially vitamin A and C, a crystalline caustic volatile alkaloid-capsaicin, which determine the great variability of the fruit's smell, flavour, taste which in turn affects consumer preference (Bhutia *et al.,* 2015).

Due to its distinct status as a delicacy from the Himalayan hills, the crop has a high commercial value in Himachal Pradesh's hilly terrain. Due to the cultivation of different local land races, the yield of this crop in most of the area is very low. Furthermore, because of its often cross-pollination behaviour, different biotic and abiotic stresses, as well as genetic drift in cultivars, are key issues for low yields (Sharma *et al.,* 2017). Green chilli fruits are immense source of vitamin C, vitamin A, B-complex (niacin, pyridoxine, riboflavin and thiamin) as well as antioxidants and minerals (Lata *et al.,* 2023). Despite its great nutritional content, consumer acceptance, and wide range of genetic variability, the optimum productivity in chilli still remains to be achieved. Therefore, it is desirable to develop a new better adaptable and productive variety through systematic breeding programme. Genetic variability is considered as an important aspect for crop improvement program for finding high yielding progenies (Bhardwaj *et al.,* 2020). Selection from the existing variations is the oldest and most effective breeding procedure. Heritability is an important parameter that determines the extent of expressivity of a trait (Sathya *et al.,* 2021). The magnitude of heritable diversity in genetic components is important for understanding their genetic constitution, which has a direct impact on their selection response. The partitioning of correlation coefficients into the direct and indirect impacts of different characters on yield becomes simple by path coefficient analysis, and it can be helpful in providing information that could help to enhance yield related traits (Sharma *et al*., 2019). The aim of any breeding program depends on genetic diversity and character association. Hence, the present investigation was carried out to determine the extent of genetic variability for important growth and fruit characters as well as to study the character association of different independent characters on dependent variable, as part of a chilli improvement programme.

The investigation was carried out with 32 chilli genotypes, including five from AICRP on vegetable crops trial and three checks *viz.,* Him Palam Mirch-1, Him Palam Mirch-2 and Surajmukhi **(Table 1)** at the Experimental Farm of Department of Vegetable Science and Floriculture, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur during summer season of the year 2020. The trial was laid out in randomized complete block design with three replications. The experimental field

Table 1. List of chilli genotypes used in the experiment along with their source

S. No.	Genotypes	Source
1	DPCH 6-2	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
2	DPCH 9 Y	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
3	DPCH 10PP	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
4	DPCH 13-1	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
5	DPCH 21	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
6	DPCH 22C	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
7	DPCH 28-12	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
8	DPCH 28-13	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
9	DPCH 29-11	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
10	DPCH 29-12	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
11	DPCH 32-11	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
12	DPCH 32-21	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
13	DPCH 33-2	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
14	DPCH 38-121	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
15	DPCH 38-122	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
16	DPCH 38-22	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
17	DPCH 39-11	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
18	DPCH 39-12	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
19	DPCH 40-2	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
20	DPCH 104-1	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
21	DPCH 501	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
22	DPCH 502	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
23	DPCH-US-1	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
24	DPCH-US-2	Department of Vegetable Science and Floriculture, CSKHPKV Palampur (HP)
25	2019/CHIVAR-1	Indian Institute of Vegetable Research, Varanasi
26	2019/CHIVAR-5	Indian Institute of Vegetable Research, Varanasi
27	2019/CHIVAR-6	Indian Institute of Vegetable Research, Varanasi
28	2019/CHIVAR-7	Indian Institute of Vegetable Research, Varanasi
29	2019/CHIVAR-9	Indian Institute of Vegetable Research, Varanasi
30	Him Palam Mirch-1	Department of Vegetable Science and Floriculture, CSKHPKV (HP)
31	Him Palam Mirch-2	Department of Vegetable Science and Floriculture, CSKHPKV (HP)
32	Surajmukhi	Department of Vegetable Science and Floriculture, CSKHPKV (HP)

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is situated at 32⁰6′ N latitude and 76⁰3′ E longitude at an altitude of 1,290.8 m above msl and represents the mid-hill zone of Himachal Pradesh, with annual precipitation of 2,500 mm. The soil is classified as Alfisolstypic Hapludalf clay with a pH of 5.7. The experimental material was sown on 28th February 2020 in the nursery bed measuring 3 m × 1 m × 15 cm in size. Eight week old seedlings were transplanted in the main field. Each genotype was planted in plots of two rows with the length of 2.25 m consisting of ten plants in each replication with inter and intra row spacing of 45 cm × 45 cm, respectively. Data was recorded on five randomly selected plants per entry per replication for various biometrical characters, *viz.* days to flowering, days to first harvest, leaf width, leaf length, leaf petiole, primary branches/plant, secondary branches/plant, plant height, fruit length, pedicel length, fruit girth, average green fruit weight, marketable green fruit number/plant, total green fruits/plant, percent marketable green fruits/ plant, marketable green fruit yield/plant, harvest duration, ascorbic acid and capsaicin content.

Analysis of Variance (ANOVA) was analyzed as per Gomez and Gomez (1983). Ascorbic acid content was recorded from the marketable green fruits by using '2,6-dichlorophenol-indophenol Visual Titration Method' as described by Ranganna (1977). The capsaicin content in the marketable green fruits was determined by Colorimetric method using Folin–Ciocalteu (FC) reagent described by Bajaj (1980).The data were analysed for estimation of genotypic, phenotypic and environmental coefficient of variation following Burton and De Vane (1953). Estimates of genotypic and phenotypic correlation were obtained using the formulae proposed by Al-Jibouri *et al.* (1958). Path coefficient was obtained according to the procedure elaborated by Dewey and Lu (1959).

The ANOVA revealed that the difference in mean performance for all characters studied in the selected chilli genotypes were significant indicating the presence of genetic variability among the genotypes and considerable scope for their improvement (**Table 2**). Earlier workers namely, Janaki *et al.* (2015) and Meena *et al.* (2016) have also revealed variability for different characters based on the result from their respective genetic materials of chilli in their respective locations.

Based on mean performance, the genotype DPCH-US-2 was observed to be earliest in duration. DPCH 502 recorded the highest fruit length and primary branches while, DPCH-13-1 had significantly more secondary branches per plant. The maximum fruit girth and average green fruit weight was found in 2019/CHIVAR-5. On the other hand, 2019/CHIVAR-7 had significantly more leaf length and leaf width in comparison to the best check Him Palam Mirch-1 (**Table 3**). Among ten genotypes which revealed significantly maximum plant height in

Table 2. Analysis of variance for yield, yield attributes of marketable green chilli

Traits	Replication	Genotypes	Error
df	**2**	**31**	**62**
Days to flowering	3.87	52.55*	5.57
Days to first harvest	7.53	67.34*	5.85
Pedicel length (cm)	0.009	0.605*	0.019
Fruit length (cm)	0.06	7.64*	0.06
Fruit girth (cm)	0.01	0.45*	0.04
Leaf petiole(cm)	0.001	2.12*	0.008
Leaf length(cm)	0.006	4.482*	0.01
Leaf width(cm)	0.01	0.88*	0.01
Primary branches per plant	0.84	0.51*	0.08
Secondary branches per plant	10.15	11.25*	0.52
Plant height (cm)	21.09	365.96*	9.49
Average green fruit weight (g)	0.03	3.92*	0.05
Marketable green fruits per plant	11.64	3129.27*	19.03
Total green fruits per plant	17.77	2701.87*	20.46
Per cent marketable green fruits per plant	0.428	162.38*	1.31
Marketable green fruit yield per plant (g)	1872.61	40214.40*	320.35
Harvest duration (days)	0.13	32.02*	8.65
Ascorbic acid (mg per 100g of fresh fruit weight)	5.99	395.99*	5.99
Capsaicin content (per cent)	0.00	0.002*	0.00

*Significant at $P \le 0.05$

Table 3. Mean performance of different genotypes of chilli for phenological and fruit traits

Traits	DTF	DTFH	PL	FL	FG	LL	LW	LP	PBPP	SBPP	PH	AGFWt.	MGFPP	TGFPP	%MGFPP	MGFYPP	HD	AA	CC
DPCH 6-2	44.33	58.33	3.58^{10}	5.54	3.21	9.66^{7}	4.21^{5}	6.06^{2}	2.83	11.69	56.97	3.67	78.61	83.89	93.75^{7}	291.31	60.67^{6}	42.36	0.20^{7}
DPCH 9Y	34.67^{2}	46.00^{3}	3.76^{6}	7.18	3.70^{2}	6.94	3.11	4.22	2.87	11.67	62.09	5.08^{7}	70.76	91.18	77.63	359.42	62.33	52.75	0.23^{4}
DPCH 10PP	41.33^{8}	52.33^{9}	3.06	9.55^{7}	2.96	7.67	2.96	3.85	2.28	11.97	79.07^{2}	5.08^{7}	73.13	95.68	76.41	370.83	60.67^{6}	60.86^{9}	0.20^{7}
DPCH 13-1	49.00	64.00	3.38	9.06	3.01	9.55^{8}	3.77	5.94^{3}	3.23^{5}	16.25^{1}	68.44^{8}	4.85^{8}	79.30	89.97	88.10	384.31	59.00^{10}	54.11	0.16
DPCH 21	43.33	56.33	2.69	7.17	2.75	7.54	3.39	4.27	2.75	13.08^{8}	66.93^{9}	2.95	103.52^{9}	119.85^{8}	86.39	305.00	61.67^{3}	62.10^{8}	0.20^{7}
DPCH 22C	43.33	55.67	3.65^{8}	7.11	2.69	10.52^{2}	4.83^{2}	5.74^{5}	3.17^{7}	13.58^{5}	51.36	3.45	88.54	92.63	95.60^{2}	305.33	61.00^{5}	39.80	0.18^{9}
DPCH 28-12	36.67^{5}	48.33^{5}	3.14	8.43	2.82	7.71	3.07	3.82	2.83	11.83	59.26	4.45	65.84	86.34	76.16	292.50	56.67	45.07	0.20^{7}
DPCH 28-13	40.67^{7}	52.00^{8}	3.11	7.53	3.42^{9}	8.95	3.73	4.10	2.77	10.08	78.96^{3}	4.52	118.03^{7}	127.20^{7}	92.79^{9}	532.92^{5}	60.67^{6}	46.59	0.20^{7}
DPCH 29-11	45.67	56.33	2.88	7.16	3.52^{6}	9.68^{6}	3.77	4.20	2.87	9.42	74.51^{5}	3.83	131.41^{4}	139.25^{5}	94.38^{6}	503.33^{7}	61.00^{5}	44.62	0.26^{1}
DPCH 29-12	43.00	54.33	2.63	6.21	3.47	8.30	3.64	4.60	2.33	9.00	91.19^{1}	4.47	128.76^{5}	137.92^{6}	93.35^{8}	574.50^{2}	59.67^{9}	55.34	0.26^{1}
DPCH 32-11	36.33^{4}	48.67^{6}	3.13	6.72	3.10	9.01	3.50	3.81	2.12	12.28^{10}	57.15	3.12	167.99^{1}	177.43^{1}	94.68^{5}	523.22^{6}	50.00	69.12^{5}	0.18^{9}
DPCH 32-21	44.00	56.00	3.25	8.73	3.49^{8}	8.25	3.73	5.24^{9}	3.20^{6}	12.00	59.24	4.83^{9}	95.28	100.12	95.16^{4}	460.42	53.00	43.95	0.20^{7}
DPCH 33-2	42.00^{9}	53.67	2.71	6.92	2.31	8.64	3.85^{9}	4.75	2.25	9.33	52.65	2.85	103.84^{8}	115.98	89.55	295.97	59.00^{10}	51.22	0.20^{7}
DPCH 38-121	36.33^{4}	48.00^{4}	3.95^{3}	11.17^{2}	3.56^{5}	7.45	3.20	5.03	2.58	9.92	57.68	5.77^{4}	78.55	90.90	86.43	452.78	56.00	77.17^{1}	0.23^{4}
DPCH 38-122	43.33	53.67	3.93^{4}	10.13^{5}	3.24	7.49	3.69	4.79	2.85	10.83	58.40	6.03^{2}	71.67	82.39	87.01	432.00	60.33^{7}	62.17^{7}	0.24^{3}
DPCH 38-22	46.67	57.00	3.56	9.28^{10}	3.08	9.27^{10}	3.79	5.13^{10}	3.00^{8}	11.00	66.02^{10}	4.43	95.75	105.75	90.52	423.75	60.67^{6}	75.96^{2}	0.22^{5}
DPCH 39-11	41.33^{8}	53.67	3.33	9.16	2.87	10.04^{4}	4.53^{3}	4.96	2.50	12.00	60.31	3.67	56.73	70.23	80.77	207.50	61.33^{4}	62.19^{6}	0.21^{6}
DPCH 39-12	42.33^{10}	53.33^{10}	2.96	9.36^{9}	2.79	8.20	3.50	5.82^{4}	2.97^{9}	14.33^{3}	56.48	3.73	81.60	92.43	88.24	304.58	62.67^{2}	46.35	0.23^{4}
DPCH 40-2	45.00	57.00	3.57	10.82^{3}	3.03	8.89	4.02^{6}	5.51^{7}	2.44	13.86^{4}	75.28^{4}	4.00	155.20^{2}	160.18^{2}	96.89^{1}	620.42^{1}	61.00^{5}	69.76^{4}	0.20^{7}
DPCH 104-1	47.67	59.33	3.15	8.99	3.41^{10}	10.06^{3}	3.84^{10}	3.52	2.92^{10}	14.67^{2}	71.88^{6}	5.58^{6}	84.00	91.08	92.22^{10}	468.33^{10}	63.00^{1}	59.97	0.25^{2}
DPCH 501	44.33	53.67	4.63^{1}	10.57^{4}	3.51^{7}	7.78	3.51	5.03	2.92^{10}	10.58	57.92	5.98^{3}	90.03	100.03	89.99	538.17^{4}	60.00^{8}	50.69	0.25^{2}
DPCH 502	46.00	56.33	4.40^{2}	11.71^{1}	3.59^{3}	9.38^{9}	3.73	4.22	3.72^{1}	13.42^{7}	61.13	5.67^{5}	100.03^{10}	112.03^{9}	89.28	566.65^{3}	60.67^{6}	53.44	0.22^{5}
DPCH-US 1	40.33^{6}	51.33^{7}	3.35	7.29	3.40	8.31	3.87^{8}	4.76	3.53^{3}	13.50^{6}	45.62	3.67	136.90^{4}	143.24^{4}	95.57^{3}	501.67^{8}	60.00^{8}	75.15^{3}	0.25^{2}
DPCH-US 2	34.00^{1}	43.67^{1}	3.14	6.64	2.83	6.71	3.38	4.32	2.67	12.83^{9}	35.65	3.67	128.64^{6}	143.48^{3}	89.64	471.67^{9}	59.00^{10}	60.36^{10}	0.26^{1}
2019/ CHIVAR 1	44.67	60.67	3.62^{9}	7.83	3.37	7.31	2.89	3.50	2.33	7.42	44.73	3.00	51.61	72.84	70.85	154.20	54.67	42.22	0.17^{10}
2019/ CHIVAR 5	35.00^{3}	44.33^{2}	3.70^{7}	9.88^{6}	3.82^{1}	7.75	3.29	6.48^{1}	3.17^{7}	9.00	50.97	7.77^{1}	50.51	62.60	80.66	391.67	57.33	47.77	0.17^{10}
2019/ CHIVAR 6	45.67	55.67	3.50	8.48	3.35	8.92	3.89^{7}	3.62	3.50^{4}	11.33	56.62	4.75^{10}	93.63	103.13^{10}	90.76	443.75	58.00	57.04	0.17^{10}
2019/ CHIVAR 7	45.67	56.67	3.81^{5}	9.22	3.58^{4}	11.65^{1}	4.98^{1}	5.56^{6}	2.75	11.00	58.47	5.08^{7}	69.59	78.67	88.46	353.33	49.67	32.26	0.20^{7}
2019/ CHIVAR 9	46.67	57.67	3.51	9.51^{8}	3.20	9.84^{5}	4.27^{4}	5.43^{8}	3.58^{2}	10.05	68.91^{7}	4.42	40.81	58.03	70.36	180.42	56.33	34.99	0.19^{9}
Him Palam Mirch-1	46.00	59.00	3.38	6.78	2.51	11.33	4.93	5.32	2.88	13.08	61.42	2.93	150.44	156.94	95.85	441.11	58.33	56.70	0.24
Him Palam Mirch-2	45.33	55.67	3.28	8.70	4.03	8.24	3.66	6.41	2.67	13.42	58.64	5.17	88.71	98.55	90.00	457.92	59.00	62.23	0.22
Surajmukhi	49.33	60.33	3.53	5.96	3.12	9.61	4.57	4.63	3.52	13.00	65.79	2.83	136.33	142.75	95.50	385.33	59.00	55.88	0.26
Mean	42.81	54.34	3.41	8.4	3.21	8.77	3.78	4.83	2.87	11.79	61.55	4.41	95.80	106.95	88.21	406.07	58.82	54.69	0.21
Range	34.00-49.33	43.67-64.00	2.63-4.63	5.54-11.71	2.31-4.03	6.71-11.65	2.89-4.98	3.50-6.48	2.12-3.72	7.42-16.25	35.65-91.19	2.83-7.77	40.81-167.99	58.03-177.43	70.36-96.89	154.20-620.42	49.67-63.00	32.26-77.17	0.16-0.26
S.E(m)	1.36	1.40	0.08	0.14	0.12	0.06	0.06	0.05	0.17	0.42	1.78	0.14	2.52	2.61	0.66	10.33	1.70	1.41	0.01
C.D (5%)	3.85	3.94	0.22	0.40	0.33	0.17	0.17	0.14	0.48	1.18	5.02	0.38	7.11	7.17	1.87	29.21	4.81	3.99	0.01
C.V (%)	5.51	4.45	4.01	2.93	6.44	1.22	2.90	1.85	10.29	6.15	5.00	5.31	4.55	4.22	1.30	4.40	5.01	4.47	5.25

Where, DTF: Days to flowering; DTFH: Days to first harvest; PL: Pedicel length (cm); FL: Fruit length (cm); FG: Fruit girth (cm); LL: Leaf length (cm); LW: Leaf width (cm); LP: Leaf petiole (cm); PBPP: Primary branches per plant; SBPP: Secondary branches per plant; PH: Plant height (cm); AGFWt.: Average green fruit weight (g); MGFPP: Marketable green fruits per plant; TGFPP: total green fruits per plant; %MGFPP: Percent marketable green fruits per plant; MGFYPP: Marketable green fruit yield per plant (g); HD: Harvest duration (days); AA: Ascorbic acid (mg/100g); CC: Capsaicin content (%)

comparison to best check ‘Surajmukhi’, DPCH-29-12, DPCH-10PP and DPCH-28-13 were placed at top three positions while DPCH-9Y and DPCH-502 performed at par with the best check ‘Surajmukhi’.

Two genotypes namely, DPCH-32-11 and DPCH-40-2 recorded significantly maximum total and marketable green fruits per plant than best check ‘Him Palam Mirch-1’. Only one genotype DPCH-40-2 was found significantly superior than best check ‘Him Palam Mirch-1’ in percent marketable green fruits per plant. Among the genotypes, DPCH-40-2 revealed the highest marketable fruit yield and significantly outperformed the best check ‘Him Palam Mirch-2’ along with ten other genotypes. Longer harvest duration was observed in genotype DPCH-104-1. Ascorbic acid has anti-oxidant properties, which helps in strengthening the immune system of the body against diseases. Five genotypes namely, DPCH-38-121, DPCH-38-22, DPCH-US1, DPCH-40-2 and DPCH-32-11 recorded significantly more ascorbic acid content to that of best check ‘Him Palam Mirch-2’ **(Table 3)**. Based on capsaicin content, six genotypes DPCH-US-2, DPCH-29-11, DPCH-US1, DPCH-29-12, DPCH-501 and DPCH-104-1 showed similar pungency to that of Surajmukhi. The value of phenotypic coefficient of variation (PCV) was slightly greater than the genotypic coefficient of variation (GCV) for all the traits studied, indicating that the environment had a considerable impact on their expression. The highest values of PCV and GCV was recorded in marketable green fruits per plant, displaying significant variability, implying that these attributes can be improved by selection. Moderate estimates of PCV and GCV was observed for most of the characters, implying that selection for these characteristics should be approached with caution. Heritability is important in understanding whether phenotypic changes in various traits are due to genetics or environmental influences. High heritability estimates was observed for traits such as leaf length followed by leaf petiole, marketable green fruits per plant, total green fruits per plant, fruit length, per cent marketable green fruits per plant, marketable green fruits yield per plant, leaf width, average green fruit weight, ascorbic acid, plant height, pedicel length and secondary branches per plant which revealed the lesser influence of environment and greater role of genetic components of variation. High heritability, on the other hand, does not always imply high genetic gain, and heredity alone is insufficient to predict improvement by simple phenotypic selection. High heritability along with high genetic advance were observed for the traits number of marketable green fruits per plant, marketable green fruit yield per plant, total green fruits per plant and average green fruit weight demonstrating the importance of additive gene activity in the expression of these traits. The results obtained in this

Table 4. Estimates of parameters of variability for various traits including marketable green crop

Traits	Environment variance	Genotypic variance	Phenotypic variance	ECV (%)	GCV (%)	PCV (%)	h^2_{bs}	GA %)
Days to flowering	5.57	15.66	21.24	5.51	9.24	10.76	73.75	16.35
Days to first harvest	5.85	20.49	26.35	4.45	8.33	9.45	77.78	15.14
Leaf width (cm)	0.01	0.29	0.30	2.91	14.26	14.55	96.02	28.79
Leaf length (cm)	0.01	1.49	1.50	1.22	13.92	13.97	99.24	28.56
Leaf petiole (cm)	0.01	0.70	0.72	1.85	17.40	17.50	98.88	35.65
Primary branches per plant	0.09	0.14	0.23	10.29	13.16	16.70	62.03	21.35
Secondary branches per plant	0.53	3.57	4.10	6.15	16.03	17.17	87.16	30.83
Plant Height (cm)	9.50	118.82	128.32	5.01	17.71	18.40	92.60	35.10
Fruit length (cm)	0.06	2.52	2.59	2.94	18.93	19.16	97.65	38.53
Pedicel length (cm)	0.02	0.19	0.21	4.01	12.95	13.56	91.22	25.47
Fruit girth (cm)	0.04	0.13	0.18	6.45	11.58	13.25	76.33	20.84
Average green fruit weight (g)	0.06	1.29	1.35	5.32	25.73	26.28	95.90	51.91
Marketable green fruits per plant	19.03	1036.74	1055.78	4.55	33.61	33.92	98.20	68.61
Total green fruits per plant	20.46	893.80	914.26	4.23	27.96	28.26	97.89	56.98
Per cent marketable green fruits per plant	1.32	53.68	55.00	1.30	8.31	8.41	97.60	16.90
Marketable green fruit yield per plant (g)	320.36	13298.01	13618.37	4.41	28.40	28.74	97.60	57.81
Harvest duration	8.69	7.78	16.47	5.01	4.74	6.90	47.21	6.71
Ascorbic acid (mg/100g)	5.99	130.00	135.99	4.48	20.85	21.32	95.60	41.99
Capsaicin content (%)	0.00	0.00	0.00	4.76	13.11	14.13	86.08	25.06

PCV and GCV represent phenotypic and genotypic coefficients of variation, respectively; h^2_{bs}: Heritability in broad sense; GA (%): Genetic advance (%) of mean

Table 5. Estimates of phenotypic and genotypic correlation coefficients for different pair of traits in marketable green chilli

Traits		DTFH	LW (cm)	LL (cm)	LP (cm)	PBPP	SBPP	PH (cm)	FL (cm)	PL (cm)	FG (cm)	AGFW (g)	MGFPP	TGFPP	%MGFPP	HD	AA (mg/100g)	CC (%)	MGFYPP (g)
DTF	P	0.941*	0.467*	0.536*	0.121	0.287*	0.206*	0.330*	0.061	0.066	0.003	-0.149	0.024	-0.037	0.243*	0.091	-0.169	-0.032	-0.019
	G	0.959*	0.546*	0.632*	0.156	0.403*	0.259*	0.381*	0.085	0.093	-0.047	-0.169	0.034	-0.032	0.273*	0.167	-0.181	0.014	-0.012
DTFH	P		0.441*	0.530*	0.099	0.197	0.216*	0.297*	-0.037	0.006	-0.092	-0.279*	0.007	-0.045	0.190	0.046	-0.196	-0.147	-0.138
	G		0.490*	0.609*	0.124	0.252*	0.261*	0.335*	-0.023	0.014	-0.144	-0.311*	0.006	-0.049	0.195	0.096	-0.202*	-0.132	-0.155
LW (cm)	P			0.872*	0.383*	0.247*	0.245*	0.036	-0.188	0.101	-0.211*	-0.295*	0.190	0.101	0.444*	-0.055	-0.228*	0.050	-0.065
	G			0.889*	0.394*	0.334*	0.259*	0.045	-0.189	0.098	-0.257*	-0.300*	0.192	0.101	0.455*	-0.070	-0.229*	0.043	-0.064
LL (cm)	P				0.248*	0.205*	0.239*	0.217*	-0.098	0.046	-0.161	-0.223*	0.137	0.059	0.358*	-0.104	-0.277*	-0.081	-0.051
	G				0.251*	0.268*	0.248*	0.219*	-0.097	0.038	-0.178	-0.228*	0.138	0.059	0.364*	-0.146	-0.284*	-0.092	-0.052
LP (cm)	P					0.163	0.179	-0.123	0.164	0.194	0.075	0.206*	-0.177	-0.257*	0.168	-0.018	-0.147	-0.151	-0.087
	G					0.206*	0.196	-0.126	0.164	0.202*	0.093	0.209*	-0.179	-0.260*	0.174	0.006	-0.158	-0.164	-0.088
PBPP	P						0.231*	-0.114	0.156	0.305*	0.134	0.193	-0.112	-0.159	0.081	0.140	-0.153	0.033	0.026
	G						0.349*	-0.145	0.174	0.441*	0.265*	0.237*	-0.148	-0.208*	0.105	0.147	-0.222*	0.025	0.015
SBPP	P							-0.001	0.043	-0.034	-0.202*	-0.122	0.241*	0.214*	0.352*	0.235*	0.247*	0.026	0.172
	G							-0.011	0.058	-0.041	-0.281*	-0.137	0.256*	0.223*	0.387*	0.354*	0.262*	0.051	0.175
PH (cm)	P								0.051	-0.273*	0.099	0.096	0.156	0.158	0.096	0.176	0.030	0.094	0.305*
	G								0.060	-0.301*	0.103	0.091	0.157	0.160	0.095	0.340*	0.028	0.113	0.306*
FL (cm)	P									0.544*	0.271*	0.666*	-0.397*	-0.404*	-0.270*	-0.017	0.156	-0.137	0.153
	G									0.571*	0.310*	0.677*	-0.401*	-0.409*	-0.271*	0.010	0.154	-0.149	0.158
PL (cm)	P										0.365*	0.475*	-0.272*	-0.303*	-0.089	-0.085	-0.032	-0.023	0.103
	G										0.421*	0.514*	-0.289*	-0.321*	-0.097	-0.108	-0.034	-0.014	0.115
FG (cm)	P											0.612*	-0.184	-0.207*	-0.055	-0.127	-0.039	0.066	0.330*
	G											0.687*	-0.212*	-0.239*	-0.055	-0.198	-0.033	0.105	0.360*
AGFW (g)	P												-0.467*	-0.489*	-0.213*	-0.010	0.002	-0.036	0.288*
	G												-0.465*	-0.486*	-0.214*	0.007	-0.006	-0.042	0.283*
MGFPP	P													0.989*	0.761*	0.003	0.412*	0.364*	0.676*
	G													0.990*	0.768*	0.011	0.427*	0.410*	0.684*
TGFPP	P														0.667*	0.003	0.430*	0.360*	0.646*
	G														0.678*	0.005	0.447*	0.409*	0.654*
%MGFPP	P															0.072	0.257*	0.318*	0.660*
	G															0.127	0.269*	0.354*	0.671*
HD	P																0.181	0.289*	0.066
	G																0.248*	0.436*	0.091
AA (mg/100g)	P																	0.269*	0.436*
	G																	0.308*	0.446*
CC (%)	P																		0.383*
	G																		0.436*

* Significant at P ≤ 0.05

DTF: Days to flowering; DTFH: Days to first harvest; LW: Leaf width (cm); LL: Leaf length (cm); LP: Leaf petiole (cm); PBPP: Primary branches per plant; SBPP: Secondary branches per plant; PH: Plant height (cm); FL: Fruit length (cm); PL: Pedicel length (cm); FG: Fruit girth (cm); AGFW.: Average green fruit weight (g); MGFPP: Marketable green fruits per plant; TGFPP: total green fruits per plant; %MGFPP: Percent marketable green fruits per plant; HD: Harvest duration (days); AA: Ascorbic acid (mg/100g); CC: Capsaicin content (%);

Table 6. Estimates of direct and indirect effects of different traits on marketable green fruit yield per plant at phenotypic (P) and genotypic (G) levels in green chilli

Traits		DTF	DTFH	LW (cm)	LL (cm)	LP (cm)	PBPP	SBPP	PH (cm)	FL (cm)	PL (cm)	FG (cm)	AGFW (g)	MGFPP	TGFPP	%MGFPP	HD	AA (mg/100g)	CC (%)	MGCY
DTF	P	**-0.074**	0.073	-0.004	-0.038	-0.010	-0.002	-0.001	0.028	0.011	0.002	0.000	-0.080	-0.004	-0.032	0.099	0.004	0.009	0.000	-0.019
	G	**0.139**	-0.077	0.095	-0.094	-0.019	-0.060	0.009	-0.012	0.019	-0.001	-0.014	-0.085	-0.017	-0.043	0.101	0.026	0.021	-0.001	-0.012
DTFH	P	-0.069	**0.078**	-0.004	-0.037	-0.008	-0.002	-0.001	0.025	-0.006	0.000	-0.011	-0.151	-0.001	-0.039	0.077	0.002	0.010	-0.002	-0.138
	G	0.133	**-0.080**	0.086	-0.091	-0.015	-0.037	0.009	-0.011	-0.005	0.000	-0.042	-0.156	-0.003	-0.065	0.072	0.015	0.024	0.011	-0.155
LW (cm)	P	-0.034	0.034	**-0.009**	-0.061	-0.030	-0.002	-0.001	0.003	-0.033	0.002	-0.024	-0.159	-0.032	0.090	0.181	-0.003	0.012	0.001	-0.065
	G	0.076	-0.039	**0.175**	-0.132	-0.049	-0.049	0.009	-0.002	-0.043	-0.001	-0.076	-0.150	-0.096	0.134	0.168	-0.011	0.027	-0.004	-0.064
LL (cm)	P	-0.040	0.041	-0.008	**-0.070**	-0.020	-0.002	-0.001	0.019	-0.017	0.001	-0.018	-0.121	-0.023	0.052	0.146	-0.005	0.014	-0.001	-0.051
	G	0.088	-0.049	0.155	**-0.149**	-0.031	-0.040	0.009	-0.007	-0.022	0.000	-0.052	-0.114	-0.069	0.078	0.134	-0.023	0.033	0.008	-0.052
LP (cm)	P	-0.009	0.008	-0.003	-0.017	**-0.079**	-0.001	-0.001	0.011	0.029	0.005	0.009	0.111	0.030	-0.230	0.068	-0.001	0.008	-0.002	-0.087
	G	0.022	-0.010	0.069	-0.037	**-0.123**	-0.030	0.007	0.004	0.037	-0.002	0.027	0.105	0.090	-0.343	0.064	0.001	0.018	0.014	-0.088
PBPP	P	-0.021	0.015	-0.002	-0.015	-0.013	**-0.008**	-0.001	0.010	0.027	0.007	0.015	0.104	0.019	-0.140	0.033	0.006	0.008	0.001	0.026
	G	0.056	-0.020	0.058	-0.040	-0.025	**-0.148**	0.012	0.005	0.039	-0.005	0.078	0.119	0.075	-0.274	0.039	0.023	0.026	-0.002	0.015
SBPP	P	-0.015	0.017	-0.002	-0.017	-0.014	-0.002	**-0.005**	0.000	0.007	-0.001	-0.023	-0.066	-0.041	0.192	0.143	0.011	-0.013	0.000	0.172
	G	0.036	-0.021	0.045	-0.037	-0.024	-0.052	**0.036**	0.000	0.013	0.000	-0.083	-0.069	-0.128	0.294	0.143	0.056	-0.031	-0.004	0.175
PH (cm)	P	-0.024	0.023	0.000	-0.015	0.010	0.001	0.000	**0.085**	0.009	-0.006	0.011	0.052	-0.026	0.140	0.039	0.008	-0.002	0.001	0.305*
	G	0.053	-0.027	0.008	-0.033	0.016	0.021	0.000	**-0.032**	0.014	0.003	0.030	0.046	-0.079	0.211	0.035	0.054	-0.003	-0.009	0.306*
FL (cm)	P	-0.005	-0.003	0.002	0.007	-0.013	-0.001	0.000	0.004	**0.174**	0.013	0.031	0.360	0.067	-0.361	0.110	-0.001	-0.008	-0.002	0.153
	G	0.012	0.002	-0.033	0.015	-0.020	-0.026	0.002	-0.002	**0.227**	-0.006	0.091	0.338	0.201	-0.538	-0.100	0.002	-0.018	0.012	0.158
PL (cm)	P	-0.005	0.001	-0.001	-0.003	-0.015	-0.002	0.000	0.023	0.095	**0.023**	0.042	0.257	0.046	-0.270	0.036	-0.004	0.002	0.000	0.103
	G	0.013	-0.001	0.017	-0.006	-0.025	-0.065	-0.002	0.010	0.129	**-0.010**	0.124	0.257	0.145	-0.423	-0.036	-0.017	0.004	0.001	0.115
FG (cm)	P	0.000	-0.007	0.002	0.011	-0.006	-0.001	0.001	0.009	0.047	0.008	**0.114**	0.331	0.031	-0.184	0.022	-0.006	0.002	0.001	0.330*
	G	-0.007	0.012	-0.045	0.027	-0.011	-0.039	-0.010	-0.003	0.070	-0.004	**0.294**	0.344	0.106	-0.315	-0.020	-0.031	0.004	-0.009	0.360*
AGFW (g)	P	0.011	-0.022	0.003	0.016	-0.016	-0.002	0.001	0.008	0.116	0.011	0.070	**0.540**	0.078	-0.437	0.087	0.000	0.000	-0.001	0.288*
	G	-0.023	0.025	-0.053	0.034	-0.026	-0.035	-0.005	-0.003	0.153	-0.005	0.202	**0.500**	0.233	-0.640	-0.079	0.001	0.001	0.004	0.283*
MGFPP	P	-0.002	0.001	-0.002	-0.010	0.014	0.001	-0.001	0.013	-0.069	-0.006	-0.021	-0.252	**-0.167**	0.884	0.310	0.000	-0.022	0.005	0.676*
	G	0.005	-0.001	0.034	-0.021	0.022	0.022	0.009	-0.005	-0.091	0.003	-0.062	-0.233	**-0.501**	1.302	0.283	0.002	-0.050	-0.034	0.684*
TGFPP	P	0.003	-0.003	-0.001	-0.004	0.020	0.001	-0.001	0.013	-0.070	-0.007	-0.024	-0.264	-0.166	**0.894**	0.272	0.000	-0.023	0.005	0.646*
	G	-0.005	0.004	0.018	-0.009	0.032	0.031	0.008	-0.005	-0.093	0.003	-0.070	-0.243	-0.496	**1.315**	0.250	0.001	-0.052	-0.034	0.654*
%MGFPP	P	-0.018	0.015	-0.004	-0.025	-0.013	-0.001	-0.002	0.008	-0.047	-0.002	-0.006	-0.115	-0.127	0.596	**0.407**	0.003	-0.013	0.004	0.660*
	G	0.038	-0.016	0.079	-0.054	-0.021	-0.016	0.014	-0.003	-0.062	0.001	-0.016	-0.107	-0.384	0.891	**0.368**	0.020	-0.031	-0.030	0.671*
HD	P	-0.007	0.004	0.001	0.007	0.001	-0.001	-0.001	0.015	-0.003	-0.002	-0.015	-0.005	-0.001	0.004	0.029	**0.046**	-0.009	0.004	0.066
	G	0.023	-0.008	-0.012	0.022	-0.001	-0.022	0.013	-0.011	0.002	0.001	-0.058	0.004	-0.005	0.005	0.047	**0.158**	-0.029	-0.036	0.091
AA (mg/100g)	P	0.013	-0.015	0.002	0.020	0.012	0.001	-0.001	0.003	0.027	-0.001	-0.004	0.001	-0.069	0.385	0.105	0.008	**-0.052**	0.004	0.436*
	G	-0.025	0.016	-0.040	0.042	0.019	0.033	0.009	-0.001	0.035	0.000	-0.010	-0.003	-0.214	0.588	0.099	0.039	**-0.117**	-0.026	0.446*
CC (%)	P	0.002	-0.011	0.000	0.006	0.012	0.000	0.000	0.008	-0.024	-0.001	0.008	-0.019	-0.061	0.322	0.130	0.013	-0.014	**0.014**	0.383*
	G	0.002	0.011	0.008	0.014	0.020	-0.004	0.002	-0.004	-0.034	0.000	0.031	-0.021	-0.205	0.537	0.131	0.069	-0.036	**-0.083**	0.436*

Residual effect at phenotypic level (P) =0.03035, and genotypic level (G) = 0.01561.

Significant at P ≤0.05; bold values indicate direct effects.;r correlation coefficient with marketable green fruit yield per plant

DTF: Days to flowering; DTFH: Days to first harvest; LW: Leaf width (cm); LL: Leaf length (cm); LP: Leaf petiole (cm); PBPP: Primary branches per plant; SBPP: Secondary branches per plant; PH: Plant height (cm); FL: Fruit length (cm); PL: Pedicel length (cm); FG: Fruit girth (cm); AGFW.: Average green fruit weight (g); MGFPP: Marketable green fruits per plant; TGFPP: total green fruits per plant; %MGFPP: Percent marketable green fruits per plant; HD: Harvest duration (days); AA: Ascorbic acid (mg/100g); CC: Capsaicin content (%); MGFYPP: Marketable green fruit yield per plant (g) study was confirmed by Sharma *et al.* (2014) and Mishra *et al.* (2015) who also reported high level of heritability and genetic advance for marketable green fruit yield in chilli (**Table 4**).

Correlation for marketable green fruit yield per plant showed positive association with marketable green fruits per plant followed by per cent marketable green fruits per plant, total green fruits per plant, ascorbic acid, capsaicin content, fruit girth, plant height and average green fruit weight at both phenotypic and genotypic levels **(Table 5)**. Earlier research workers have also revealed positive and significant correlation of marketable green fruit yield per plant with plant height (Negi and Sharma, 2019), marketable green fruits per plant (Hasan *et al.,* 2016) and total green fruits per plant (Srinivas *et al.,* 2020). Selection based on these features may result in increased yield, and these should be given specific attention for improving green fruit output. A positive and significant association of days to flowering with days to first harvest observed in the study indicated that early maturing genotypes would be an appropriate selection criterion to get early yield. In addition, positive and significant associations at both phenotypic and genotypic levels was recorded for secondary branches per plant with percent marketable green fruits per plant, harvest duration, ascorbic acid, marketable green fruits per plant and total green fruits per plant which revealed that improvement in these traits would enhance green fruits/ plant and ultimately yield.

Path analysis exposed that total green fruits per plant had the maximum positive direct effect on marketable green fruit yield per plant at both phenotypic and genotypic levels followed by average green fruit weight, per cent marketable green fruits per plant, fruit girth and fruit length indicating the importance of these qualities in a yield-improving selection programme (**Table 6**). These results are also in consonance with the results of Patel *et al.* (2015) for average fruit weight, plant height (Negi and Sharma, 2019) and fruit length (Deepo *et al.,* 2020) on marketable green fruit yield per plant. In addition, plant height and days to first harvest at phenotypic level with low magnitude whereas, leaf width and days to flowering at genotypic level with considerable magnitude also contributed directly towards marketable green fruit yield per plant. The positive indirect effect *via* total green fruits per plant, average green fruit weight and per cent marketable green fruits per plant were the main contributor to the correlation between plant height, fruit girth, average green fruit weight, marketable green fruits per plant, total green fruits per plant, per cent marketable green fruits per plant, ascorbic acid, capsaicin content and marketable green fruit yield per plant.

Based on the present study, it can be concluded that 'DPCH-40-2', 'DPCH-29-12', 'DPCH-502', 'DPCH-501', 'DPCH-28-13', 'DPCH-32-11', 'DPCH-29-11', 'DPCH-US-1', 'DPCH-US-2', 'DPCH-104-1' and 'DPCH-32-21' were the top perfoming genotypes for marketable green fruit yield per plant. High PCV, GCV, heritability and genetic advance were noted for marketable green fruits/plant, total green fruits/plant along with fruit length, average fruit weight and secondary branches per plant. The correlation and direct and indirect effects suggested to focus on plant height, average green fruit weight, fruit length, fruit girth, marketable green fruits/plant, total green fruits/plant and percent marketable green fruits/plant to frame profitable approach for developing high producing chilli genotypes. These traits would be a paying preposition for the improvement of chilli for green fruit yield.

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