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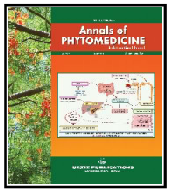

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Per se performance revealed exploitable variability for nutritional quality and yield traits in chilli (*Capsicum annuum* L.) germplasm

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Abstract

To assess *per se* performance, thirty-six genotypes along with 4 checks were investigated in a RBD in Kharif, 2019 at ICAR-NBPGR Regional Station, Hyderabad, Telangana state. The analysis of variance for quality and yield characters revealed significant genetic variations among 40 genotypes for 10 traits in the current investigation. The result of the mean performance of forty genotypes for ten traits revealed that EC-596940 was best in performance for mean fruit weight (13.30 g), per plant fruit yield (0.439 kg) and per hectare fruit yield (21933.3 kg). Genotype IC-561670 had performed superior for ascorbic acid (134.01 mg/100g). High capsanthin content (358.67 ASTA units) in genotype IC-208534 and maximum chlorophyll content (2.32 %) in EC-628901 were registered. Genotype IC-561673 was found superior for capsaicin content (0.58%). Three genotypes, *viz*., EC-596940, IC-278055, and IC-561614 were found to be best and promising based on their *per se* performances for yield and its attributing traits. Genotypes, IC-561670, IC-561614, EC-628901, IC-528876, IC-208534, EC-402105, IC-561673 and IC-561619 were identified as promising ones for four quality parameters. Hence, these identified chilli genotypes can be released for commercial cultivation for the farmers after multi-location trials and over varied seasons.

1. Introduction

Chilli, or hot pepper, *Capsicum annuum* L. is a farmer-appreciated commercial spice (dried) and vegetable (green pods) crop, that belongs to the family, Solanaceae. India is leading in chilli production (3737 thousand tones of production from 3,66,000 ha cultivable area), consumption and export. In India, its average productivity is 1.93 tonnes per hectare (NHB Database, 2018-19). Within India, Telangana ranks 2nd in chilli production (279.8 tonnes) from an area of 78.90 ha. The productivity (3.54 t/ha) of Telangana chilli is higher than that of the country's productivity (NHB Database, 2018-19). Chilli is preferred for pungency and pleasant flavour, which is due to capsaicinoid production, which is exclusive in the genus, *Capsicum* only. However, the amount of compound differs based on varieties under farming, seasons of cultivation and places of their origin (Prasath *et al.,* 2007). In general, the fruits are often consumed at green or red or partial red-ripen or fully red ripen stages as vegetables or as spice after drying at full maturity. Dried chillies' red colour is mainly attributed to capsanthin and capsorubin. Capsaicin produces pungency in fruits that are placed in the placenta of fruits. Capsaicin is because of its antibacterial, analgesic, antidiabetic and anti-carcinogenic actions, which has varied pharma applications and preparations and is also being used in developing medicinal ointments for chest congestion, sore throat, cold, *etc*. While, in beauty products and cosmetics (prickly heat powders and skin ointments), capsaicin is the major ingredient. The amount of capsaicin varies in green and red chillies, the range being, in green chilli, between 160-210 mg/g and between 113-116 mg/100 g in red chillies. Chlorophyll content is highest in early green fruits; ascorbic acid content is highest in mature green fruit, while carotenoid content is higher in red ripe fruit (Acharya *et al.,* 2007; Pallerla Saisupriya *et al*., 2021). Post-COVID, the consumption of green chillies increased due to their richness of supplying chlorophyll content and ascorbic acid, which helps in human immunity.

The chilli crop had acquired sufficient genetic variability due to its long history in cultivation, and selection pressures applied for trait

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manipulations. Rich variability in morpho-physiological characters in hot chillies was reported across different states of India. The eastern foothills of the Himalayas and Gangetic plains of the South peninsular region are reported for innate germplasm existence and varied performances. Yield by genetic nature is a complex trait governed by a large number of component traits conditioned by additive genes. To conclude yield enhancement at an optimal selection index, cause and effect relationship between dependant-yield and independent component characters is always a baseline. The critical assessment of each variable genetic resource is the basic prerequisite for engaging result-oriented breeding methods for directed and desired genetic enhancement. To initiate any result-oriented breeding research, it is always crucial to assess *per se* performance in the intended indigenous germplasm lines for yield, its attributes and quality traits. Thereby, the identification of promising genotypes to explore them in further breeding programmes is robust. Given the above emphasis, to select the best-performing chilli germplasm with a superior-yielding nature and assess for quantifiable quality traits for commercial application of the results, the present research was taken up.

2. Material and Methods

The experiment was investigated during Kharif, 2019 at ICAR-NBPGR Regional Station, Rajendranagar, Hyderabad. The experimental location is situated at an altitude of 542.6 meters above mean sea level (MSL) with a geographical bearing of 79°-23' East longitude and 17°-19' North latitude.

2.1 Experimental materials

The experimental materials (Table 1) comprised 40 (36 elite lines and 4 checks) chilli genotypes obtained from ICAR-NBPGR Regional Station, Rajendranagar, Hyderabad (Arka Lohit from IIRH, Indian Institute of Horticultural Research, Banglore, CA-960 and LCA-334 from HRS, Lam Farm, Guntur and Pusa Jwala from IARI, New Delhi) and evaluated for 10 quantitative and qualitative traits. The experiment was investigated in a completely randomized block design (CRBD) with 40 chilli germplasm during the Kharif season, 2019 at ICAR-NBPGR Regional Station, Hyderabad, Telangana state. Treatments were randomized and replicated to reduce fertility gradients and environmental errors.

Table 1: List of germplasm lines of chilli (*Capsicum annuum* L.) selected for the present study

Genotype	Genotype	Genotype	Genotype
EC-378630	IC-278055	IC-447065	IC-561688
EC-378635	IC-284474	IC-526432	IC-561691
EC-391083	IC-324215	IC-528876	IC-561694
EC-402105	IC-329995	IC-528879	IC-561695
EC-405253	IC-330193	IC-561614	IC-561715
EC-566920	IC-332924	IC-561619	IC-561723
EC-596940	IC-335340	IC-561640	ArkaLohit
EC-599969	IC-363905	IC-561670	CA-960
EC-628901	IC-394731	IC-561673	LCA-334
IC-208534	IC-419750	IC-561679	Pusa Jwala

2.1.1 Nursery raising

The chilli germplasm seed was sown in the plug trays on 10th June 2019 and the seedlings were transplanted on 17th July 2019 to the main field. The field was thoroughly ploughed thrice and levelled. The recommended dose of manures and fertilizers were incorporated at the final levelling. All the recommended fertilizer and agronomic practices were adapted to raise a healthy and non-stress chilli crop.

2.1.2 Main field transplanting and aftercare

Five weeks (40 days) old healthy chilli seedlings were transplanted in the main field duly allotting entries randomly in each of the three replications. Each germplasm was grown in a plot area of 1.8 m × 2.4 m (4.32 sq. meters), with a spacing of 60×60 cm. A required number of irrigations, weed management and need-based plant protection measures were taken to raise a healthy chilli crop. The data on different quantitative parameters and quality traits were recorded by selecting and tagging five plants at random in each replication.

2.2 Methods

2.2.1 Estimation of ascorbic acid (mg/100 g of fruit)

The ascorbic acid of each chilli accession in the experiment replication-wise was estimated as per the procedure developed (Ranganna, 1986). The ascorbic acid was calculated by using the formula:

Ascorbic acid (mg/100 g) =

$$\frac{\text{Titre} \times \text{Dye factor} \times \text{Volume made up}}{\text{Aliquot of extract} \times \text{Weight of sample taken for extraction}} \times 100$$

Here, Titre = Volume of dye used to titrate the aliquot of extract of a given sample.

2.2.2 Estimation of chlorophyll content of green chilli (%)

All the 40 accessions were estimated for chlorophyll contents. For measuring total chlorophyll content, fresh green mature chillies were used. A standard procedure for extracting chlorophyll content using dimethyl sulphoxide (DMSO) was employed.

2.2.3 Estimation of capsanthin content (ASTA units)

The capsanthin content of fruits of each chilli genetic resource was estimated in American Spice Trade Association units (ASTA, 1986). ASTA colour units were calculated as per the formula:

ASTA= (Absorbance at 460 nm / Weight of sample in grams) x 100

2.2.4 Estimation of capsaicin content (%)

The colourimetric method, described by Balasubramanian *et al.* (1982) was used to estimate the fruit capsaicin content of each chilli accession.

2.3 Statistical analysis

The field and lab data collected on 10 characters were analysed attributing to the analysis of variance for randomized block design (RBD) (Panse and Sukhatme,1985).

3. Results

3.1 Analysis of variance

The data on analysis of variance (ANOVA) for yield, its attributes and quality traits are presented in Table 2. The mean sum of squares (MSS) for genotypes was found to be significant for the 10 characters, *viz.,* fruit length (cm), fruit diameter (cm), average fresh fruit weight (g), per plant number of fruits, per plant fresh fruit yield (kg/plant), per hectare fresh fruit yield (kg/ha), ascorbic acid content (mg/100 g of fruit), chlorophyll of green chilli (%), capsanthin (ASTA units) and capsaicin (%). While, the highest values were recorded for per hectare fruit yield followed by capsanthin, ascorbic acid, per plant fruits, average fruit weight and length of the fruit, which indicated that the genotypes under investigation were different statistically from each other and they are genetically different as the error due to replications is noncontributing. Similarly, the mean sum of squares of replications was also non-significant revealing that environmental error is eliminated. Hence, differences among genotypes are free from existing environmental influence and driven by their genetic potential.

Table 2: RBD ANOVA of yield, yield attributes and quality traits in 40 germplasm of chilli

Character	Mean sum of squares		
	Replications (d.f. = 2)	Genotypes/treatments (d.f. = 39)	Error (d.f. = 78)
Fruit length (cm)	0.382	17.755***	0.42
Fruit diameter (cm)	0.077	0.397***	0.02
Number of fruits per plant	18.225	924.245***	72.29
Average fruit weight (g)	0.155	30.605***	0.82
Per plant fruit yield (kg/plant)	0.001	0.038***	0.01
Fruit yield per hectare (kg/ha)	2773408	95955965.165***	6023858.56
Ascorbic acid content (mg/100 g)	0.681	1985.566***	0.29
Capsanthin (ASTA unit)	9.100	10773.365***	5.00
Capsaicin (%)	0.000	0.042***	0.00
Chlorophyll content of green fruits (%)	0.009	0.441***	0.00

*** significant at p=0.005 levels

3.2 Fruit yield and its characters

The mean performance of 40 genotypes of chilli for 10 biometric traits and qualitative characters are presented in Tables 3 and 4.

3.2.1 Chilli fruit length (cm)

The chilli fruit length ranged between 4.60 cm to 13.70 cm with a grand mean of 8.98 cm. EC-596940 had the maximum length of the fruit (13.70 cm), while the minimum (4.60 cm) was recorded in two genotypes, IC-335340 and IC-528879. Six genotypes, *viz.*, EC-391083 (12.60 cm), EC-596940 (13.70 cm), EC-599969 (11.67 cm), IC-208534 (11.63 cm), IC-561679 (12.63 cm) and IC-561715 (13.43 cm) recorded significantly lengthy fruits than the best check Pusa Jwala (11.60 cm).

3.2.2 Chilli fruit diameter (cm)

The chilli fruit diameter mean values were between 0.83 cm to 2.16 cm with a total mean of 1.26 cm. IC-561619 (2.16 cm) and IC-332924 (0.83 cm) showed maximum and minimum fruit diameters, respectively. Sixteen genotypes, *viz.*, EC-378630 (1.26 cm), EC-378635 (1.46 cm), EC-405253 (1.50 cm), EC-596940 (1.86 cm), EC-599969 (1.43 cm), IC-208534 (1.56 cm), IC-528879 (1.36 cm), IC-526432 (1.30 cm), IC-561614 (1.86 cm), IC-561619 (2.16 cm), IC-561640 (1.60 cm), IC-561688 (1.40 cm), IC-561691 (1.30 cm), IC-561694 (2.03 cm), IC-561715 (1.80 cm) and IC-561723 (2.06 cm) were the genotypes with higher fruit diameter than LCA-334 (1.20 cm), whereas IC-561695 (1.23 cm) was statistically on par with check LCA-334.

3.2.3 Average fruit weight (g)

The average fruit weight of 40 chilli genotypes was 5.75g and ranged (Figure 1) between 2.31 g to 15.03 g. IC-561614 (15.03 g) and 394731(2.31 g) registered maximum and minimum average fruit weights, respectively. Eight genotypes, *viz.,* EC-391083 (8.85 g), EC-596940 (13.30 g), EC-599969 (7.50 g), IC-208534 (8.01 g), IC-561614 (15.03 g), IC-561619 (13.41 g), IC-561691 (7.87 g) and IC-561715 (13.29 g) recorded significant and higher average fresh fruit weights than LCA-334 (6.20 g), which was a best check. Whereas, the other four genotypes EC-566920 (6.59 g), IC-561640 (6.85 g), IC-561695 (6.99 g), and IC-561723 (6.68 g) were statistically on par with check, LCA-334.

3.2.4 Fruits per individual plant

The average number of fruits formed per plant was between 17.33 to 91.33 and registered a grand average of 39.02. The maximum and minimum fruits per plant were recorded by IC-278055 (91.33) and IC-561640 (17.33). Only one genotype, IC-278055 (91.33) recorded a higher per plant fruits than the two best checks, Arka Lohit (65.00) and LCA-334 (65.33). Whereas, IC-394731 (66.33) was statistically at par with the best checks, Arka Lohit and LCA-334.

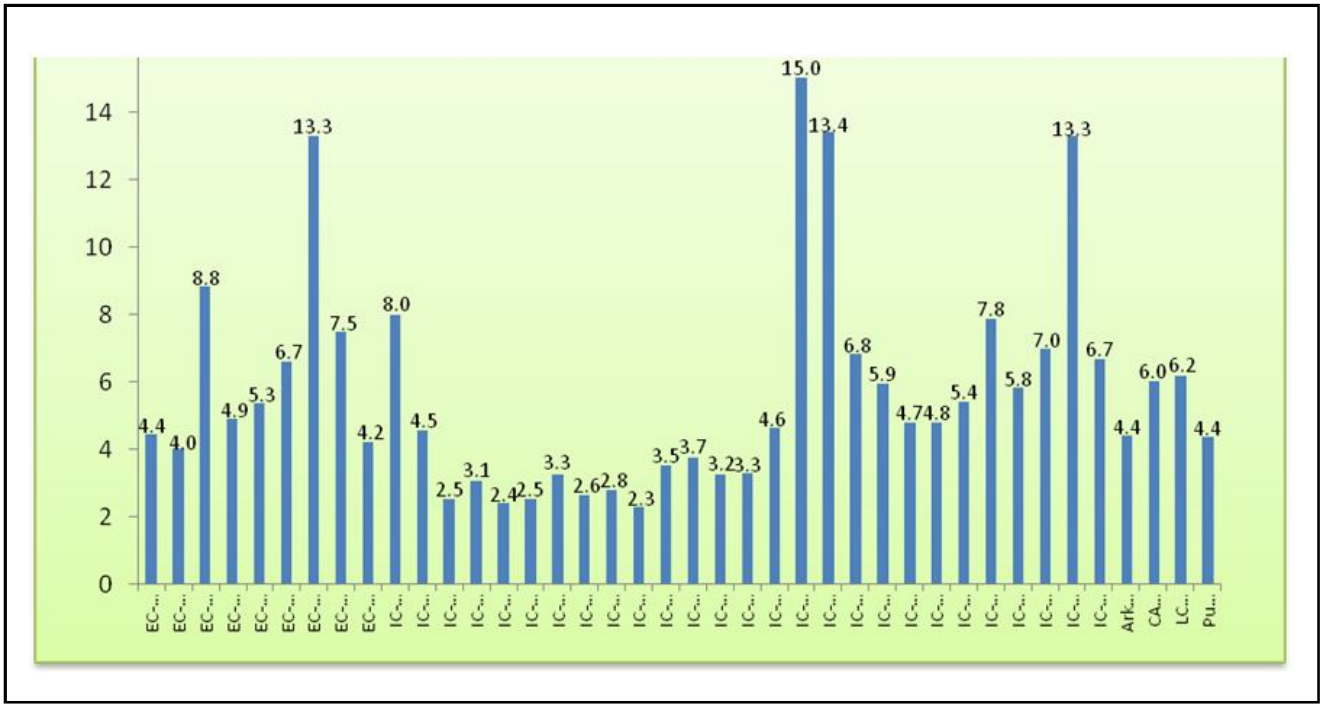

Figure 1: Average fresh fruit weight (g) of 40 chilli genotypes.

Table 3: Performance of 40 chilli genotypes for various yield and quality traits

Genotype	PH	PS	NPBP	DFF (DAT)	D 50% F (DAT)	DFH (DAT)	DLH (DAT)	AFW	FL	FD	NFPP	FYPP	FYPH
EC-378630	76.67	63.66	4.66	33.33	47.33	98.33	146.33	4.46	10.53	1.26	57.00	0.254	12,700.0
EC-378635	92.66	62.00	4.67	22.33	33.00	80.67	128.33	4.02	8.30	1.46	31.33	0.125	6,266.6
EC-391083	49.67	59.33	6.00	28.00	49.33	98.33	134.66	8.85	12.60	1.13	36.00	0.318	15,900.0
EC-402105	104.00	57.00	4.33	42.33	54.33	100.33	142.33	4.91	11.16	1.13	19.00	0.093	4,650.0
EC-405253	68.33	54.33	4.33	26.33	45.00	89.33	128.66	5.38	6.50	1.50	32.00	0.172	8,583.3
EC-566920	78.67	64.67	4.67	31.33	35.33	77.67	120.00	6.59	9.96	1.20	53.00	0.349	17,466.6
EC-596940	45.66	54.33	4.00	26.33	35.33	74.66	132.66	13.30	13.70	1.86	33.00	0.439	21,933.3
EC-599969	56.00	71.67	3.67	35.33	47.33	94.33	138.33	7.50	11.67	1.43	49.00	0.367	18,366.6
EC-628901	56.33	48.66	6.00	39.00	52.33	97.66	135.33	4.23	9.76	1.00	52.00	0.220	10,983.3
IC-208534	84.33	74.00	6.00	26.00	46.33	89.33	156.33	8.01	11.63	1.56	43.33	0.347	17,341.6
IC-278055	70.67	72.33	7.00	31.33	49.33	93.00	148.00	4.57	9.46	0.86	91.33	0.417	20,833.3
IC-284474	74.67	58.33	5.00	31.33	47.33	90.67	146.66	2.52	7.63	0.90	32.33	0.081	4,050.0
IC-324215	86.33	67.33	5.00	31.33	49.33	89.67	144.66	3.08	7.13	0.93	23.66	0.073	3,643.3
IC-329995	84.00	63.66	4.33	35.33	49.33	91.66	128.33	2.42	7.36	0.90	29.33	0.071	3,533.3
IC-330193	85.67	79.33	4.33	26.33	33.00	73.33	137.33	2.53	5.80	0.96	34.67	0.088	4,383.3
IC-332924	95.66	58.33	5.00	38.33	49.33	94.67	139.66	3.27	7.10	0.83	64.33	0.210	10,500.0
IC-335340	91.33	55.67	4.00	31.33	42.33	82.00	133.33	2.65	4.60	1.06	27.33	0.072	3,610.0
IC-363905	93.33	87.33	5.00	26.33	42.33	88.66	138.00	2.81	6.90	0.86	28.66	0.080	4,000.0

IC-394731	94.00	71.33	5.33	26.66	49.33	91.66	143.33	2.31	8.70	0.90	66.33	0.153	7,666.6
IC-419750	102.00	68.00	5.33	38.00	47.33	93.33	144.33	3.53	6.03	1.20	52.00	0.183	9,166.6
IC-447065	95.33	39.67	4.33	33.33	52.33	101.67	143.66	3.75	7.16	1.13	28.00	0.105	5,233.3
IC-526432	75.00	65.67	4.67	31.33	42.33	84.67	138.33	3.28	5.33	1.30	58.33	0.191	9,566.6
IC-528876	93.00	59.66	5.00	26.33	35.33	79.67	129.66	3.29	7.76	1.03	40.33	0.132	6,616.6
IC-528879	95.33	69.33	4.66	26.00	45.00	92.66	151.66	4.64	4.60	1.36	35.66	0.165	8,266.7
IC-561614	82.33	47.66	3.66	26.33	31.33	74.66	126.66	15.03	10.93	1.86	27.00	0.406	20,283.3
IC-561619	88.66	47.66	4.00	13.33	35.33	76.67	128.33	13.41	10.26	2.16	20.00	0.268	13,383.3
IC-561640	80.00	54.33	4.67	18.33	42.33	85.00	129.66	6.85	9.20	1.60	17.33	0.118	5,916.6
IC-561670	97.67	62.33	4.67	18.33	33.33	74.66	130.00	5.94	10.30	1.20	65.00	0.386	19,300.0
IC-561673	75.66	36.00	4.00	18.33	31.00	69.67	119.66	4.79	7.93	1.20	25.00	0.120	5,976.6
IC-561679	89.66	64.67	5.33	20.00	33.00	77.67	129.66	4.81	12.63	0.86	25.33	0.121	6,050.0
IC-561688	64.66	58.00	4.67	26.00	33.33	73.33	124.66	5.41	8.50	1.40	19.00	0.102	5,121.7
IC-561691	78.00	68.33	5.66	20.33	31.33	78.00	129.66	7.87	10.30	1.30	28.33	0.223	11,133.3
IC-561694	84.00	66.00	4.33	31.33	45.33	96.67	144.33	5.85	6.80	2.03	18.33	0.107	5,333.3
IC-561695	77.33	55.33	4.33	26.33	35.34	81.00	139.66	6.99	11.06	1.23	39.67	0.277	13,846.6
IC-561715	70.33	67.33	3.66	26.00	42.33	87.33	133.33	13.29	13.43	1.80	19.67	0.261	13,050.0
IC-561723	93.33	57.33	4.67	26.33	31.33	78.00	128.33	6.68	6.23	2.06	21.00	0.140	6,991.6
Arka Lohit	89.66	63.67	5.00	36.00	44.00	84.33	126.00	4.43	7.76	0.86	65.00	0.288	14,383.3
CA-960	87.67	55.00	4.33	31.33	40.33	94.67	146.66	6.04	11.40	1.00	35.33	0.213	10,650.0
LCA-334	87.33	65.00	5.67	42.00	53.33	101.00	156.00	6.20	9.43	1.20	65.33	0.405	20,266.6
Pusa Jwala	68.33	63.33	5.33	42.00	51.33	98.00	144.66	4.40	11.60	1.10	51.67	0.227	11,333.3
Mean	81.58	61.44	4.78	29.15	42.35	86.96	136.68	5.75	8.98	1.26	39.02	0.209	10457.04
CV	9.53	11.32	16.94	14.59	12.56	9.59	4.99	15.72	7.20	11.28	21.78	23.567	23.47
SE_d	6.34	5.68	0.66	3.47	4.34	6.81	5.57	0.73	0.52	0.11	6.94	0.040	2003.97
CD (5%)	12.66	11.31	1.31	6.93	8.66	13.59	11.09	1.47	1.05	0.23	13.84	0.080	3989.62

PH- Plant height (cm), PS- Plant spread (cm), NPBP- Number of primary branches per plant, DFF- Days to first flowering, D50%F- Days to 50 per cent flowering, DFH- Days to first harvest, DLH- Days to last harvest, AFW- Average fruit weight (g), FL- Fruit length (cm), FD- Fruit diameter (cm), NFPP– Number of fruits per plant, FYPP- Fruit yield per plant (kg/plant), FYPH- Fruit yield per hectare (kg/ha).

3.2.5 Per plant fresh fruit yield (kg/plant)

Per plant chilli fresh fruit yield was between 0.071 kg to 0.439 kg (Figure 2), with a grand mean of 0.209 kg. A maximum of 0.439 kg by EC-596940 and a minimum of 0.071 kg by IC-329995 per plant fresh fruit yield were registered. Two genotypes, EC-596940 (0.439 kg) and IC-278055 (0.417 kg) recorded higher per plant fresh fruit yield compared to that of LCA-334 (0.405 kg), Whereas, IC-561614 (0.406 kg) was statistically on par with the best check, LCA-334.

3.2.6 Per hectare fresh fruit yield (kg/ha)

Chilli per hectare fresh fruit yield ranged from 3533.30 kg to 21933.30 kg with a grand mean of 10457.04 kg. The maximum and minimum per hectare fruit yields were reported by EC-596940 (21933.3 kg) and IC-329995 (3533.3 kg), respectively. Three genotypes EC-596940 (21933.3 kg), IC-278055 (20833.3 kg) and IC-561614 (20283.3 kg) registered significant and superior per hectare fresh fruit yield to that of LCA-334 (20266.6 kg), the best check variety in the present study.

3.3 Fruit quality traits

The *per se* performance of the ascorbic acid, capsaicin, capsanthin and chlorophyll content is presented in Table 5 trait-wise and is discussed under individual head-trait-wise.

3.3.1 Ascorbic acid (mg per 100 g of fruit)

A range of 39.21 mg/100 g to 134.01 mg/100 g, with a total average of 84.23 mg/100 g ascorbic acid (Figure 3) was reported for the 40 chilli accessions. IC-561670 with a maximum (134.01 mg/100 g) and IC-

335340 with a minimum (39.21 mg/100 g) ascorbic acids, respectively, were reported. Four genotypes, IC-526432 (127.32 mg/100 g), IC-561614 (129.55 mg/100 g, IC-561640 (128.34 mg/100 g) and IC-561670 (134.01 mg/100 g) recorded significant and better for ascorbic acid exploitation compared to that of Arka Lohit (126 mg/100 g), the best ascorbic acid check.

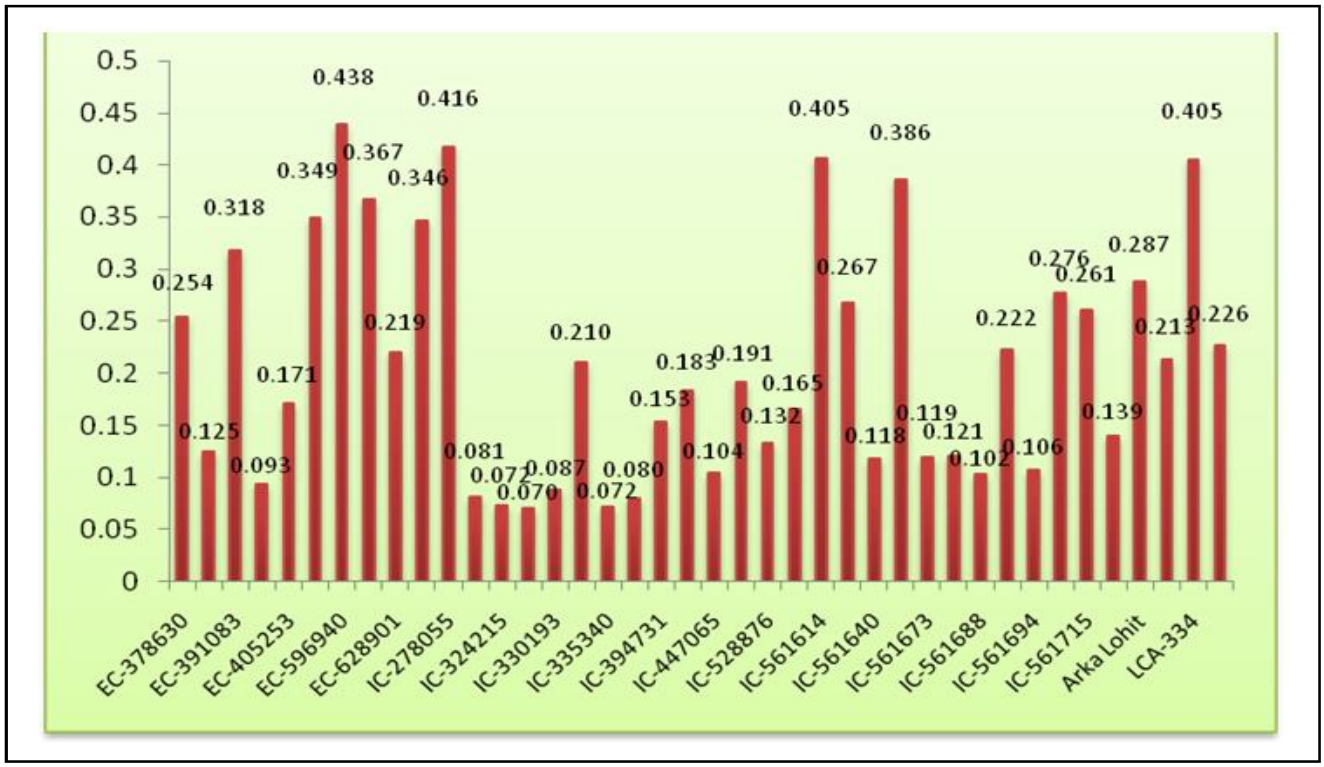

Figure 2: Fresh fruit yield per plant (kg/plant) of 40 chilli genotypes.

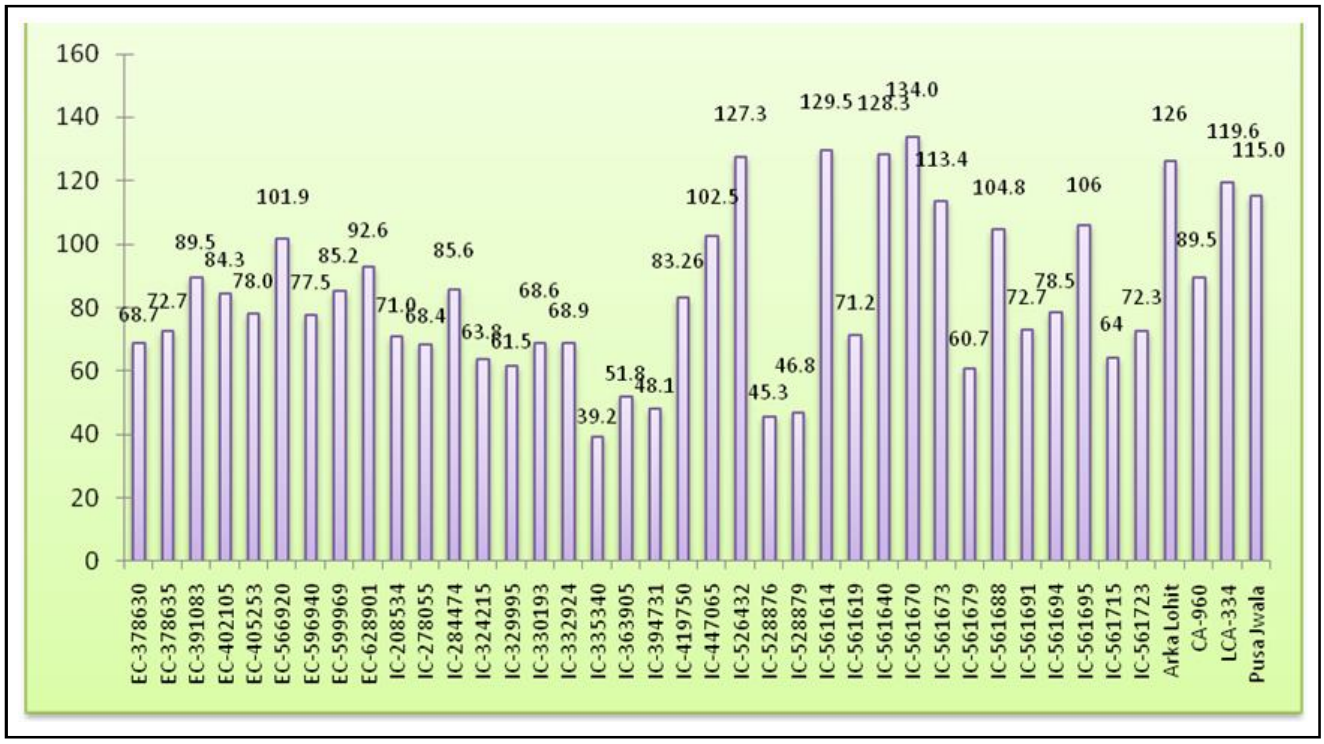

Figure 3: Ascorbic acid content (mg per 100 g of fruit) of 40 chilli genotypes.

Table 5: Mean values of the quality traits in 40 chilli genotypes

Genotype	ASA	CLC	CPSN	CPSI
EC-378630	68.75	2.08	128.33	0.35
EC-378635	72.70	2.17	193.33	0.28
EC-391083	89.52	2.22	255.67	0.14
EC-402105	84.36	1.78	340.00	0.25
EC-405253	78.00	1.91	201.00	0.13
EC-566920	101.91	2.12	237.33	0.37
EC-596940	77.53	1.91	297.33	0.17
EC-599969	85.26	2.07	217.33	0.37
EC-628901	92.63	2.32	238.00	0.26
IC-208534	71.02	1.73	358.67	0.21
IC-278055	68.45	1.38	166.00	0.52
IC-284474	85.68	2.24	190.33	0.17
IC-324215	63.85	2.17	138.67	0.36
IC-329995	61.57	2.06	226.33	0.22
IC-330193	68.63	1.98	328.00	0.26
IC-332924	68.96	1.85	238.33	0.33
IC-335340	39.21	2.20	309.00	0.31
IC-363905	51.89	2.00	238.00	0.19
IC-394731	48.18	1.65	188.00	0.45
IC-419750	83.26	0.78	244.33	0.26
IC-447065	102.52	1.63	202.00	0.32
IC-526432	127.32	2.19	142.00	0.49
IC-528876	45.38	2.29	127.67	0.16
IC-528879	46.84	0.38	262.00	0.19
IC-561614	129.55	2.00	227.00	0.22
IC-561619	71.20	1.50	314.66	0.53
IC-561640	128.34	2.02	197.00	0.27
IC-561670	134.01	2.21	239.67	0.12
IC-561673	113.47	1.89	219.33	0.58
IC-561679	60.70	1.96	234.33	0.32
IC-561688	104.80	2.11	137.67	0.33
IC-561691	72.78	1.77	197.33	0.39
IC-561694	78.50	1.80	289.00	0.26
IC-561695	106.00	2.15	151.00	0.29
IC-561715	64.00	2.26	192.33	0.51
IC-561723	72.37	2.17	151.33	0.19
Arka Lohit	126.00	2.17	290.00	0.21
CA-960	89.59	1.89	195.00	0.19
LCA-334	119.63	1.80	243.00	0.35
Pusa Jwala	115.01	2.06	272.67	0.20
Mean	84.23	1.92	225.47	0.29
CV	0.63	5.13	0.99	5.13
$S.E_d$	0.44	0.60	1.82	0.01
CD (5%)	0.87	0.11	3.64	0.02

ASA- Ascorbic acid (mg/100 g), CLC- Chlorophyll content of green fruits (%), CPSN- Capsanthin (ASTA unit), CPSI- Capsaicin (%)CPSN.

3.3.2 Capsanthin (ASTA units)

A range of 127.67 ASTA units to 358.67 ASTA units among 40 genotypes and an average of 225.47 ASTA units were reported for chilli capsanthin (Figure 4) in the present research. The maximum and minimum capsanthin contents were reported in IC-208534 (358.67 ASTA units) and IC-528876 (127.67 ASTA units). Five genotypes, *viz*., EC-596940 (297.33 ASTA units), IC-208534 (358.67 ASTA units), IC-330193 (328.00 ASTA units), IC-335340 (309.00 ASTA units) and IC-561619 (314.66 ASTA units) noted with significant and better capsanthin values compared to that of Arka Lohit (290.00 ASTA units), the best check for this trait.

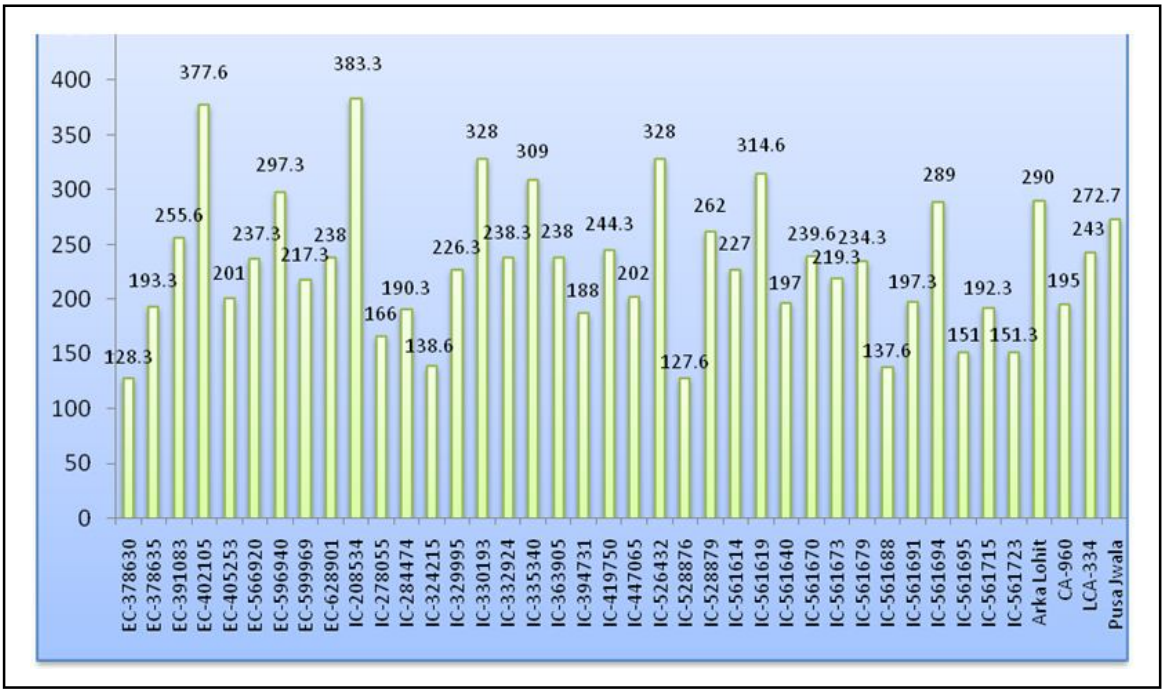

Figure 4: Capsanthin content (ASTA units) of 40 chilli genotypes.

3.3.3 Capsaicin content (%)

A total mean of 0.29% with a range of 0.12 % to 0.58% was reported for capsaicin for chilli germplasm investigated (Figure 5). Of the 40 genotypes, maximum (0.58 %) in IC-561673 and minimum (0.12 %) in IC-561670, capsaicin contents were reported. Eleven genotypes, *viz*., EC-378630 (0.35 %), EC-566920 (0.37 %), EC-599969 (0.37 %), IC-278055 (0.52 %), IC-324215 (0.36 %), IC-394731 (0.45 %), IC-526432 (0.49 %), IC-561619 (0.53 %), IC-561673 (0.58 %), IC-561691 (0.39 %) and IC-561715 (0.51 %) were with significant and higher capsaicin amounts compared with that of LCA-334 (0.35 %) (Best check variety).

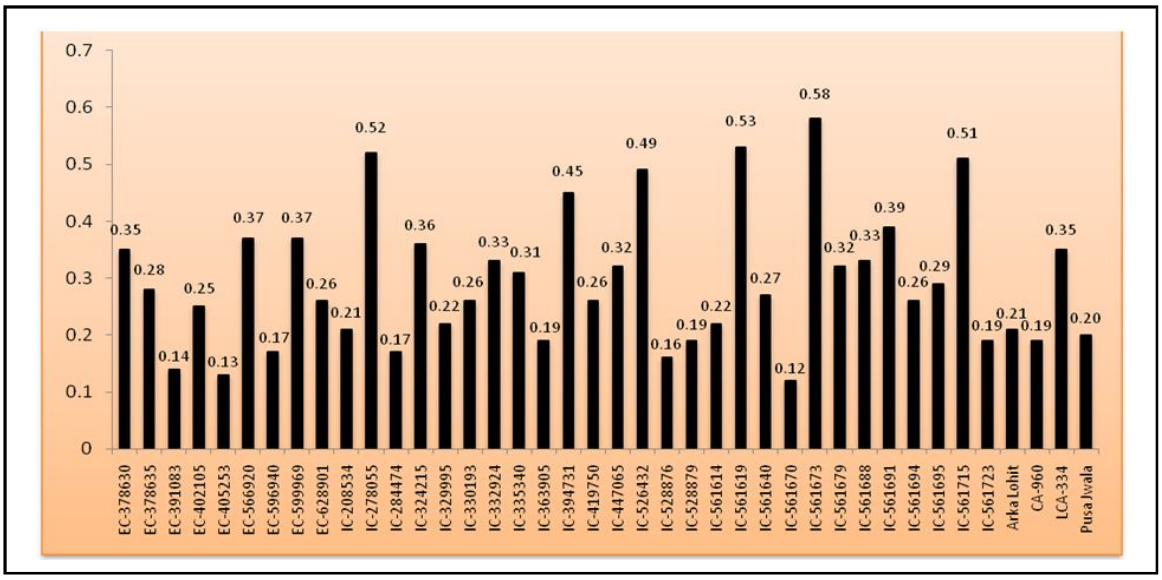

Figure 5: Capsaicin (%) of 40 chilli genotypes.

3.3.4 Chlorophyll content of green chilli (%)

For chlorophyll of 40 chillies, 0.38 % to 2.32 % was the range and 1.92 % was the mean (Figure 6) reported in the present investigation. EC-628901 (2.32 %) and IC-528879 (0.38 %) were the two chilli germplasms, which registered maximum and minimum chlorophyll contents, respectively. Ten chilli genetic resources, namely, EC-378635 (2.17 %), EC-391083 (2.22 %), EC-628901 (2.32 %), IC-284474 (2.24 %), IC-324215 (2.17 %), IC-335340 (2.20 %), IC-526432 (2.19 %), IC-528876 (2.29 %), IC-561670 (2.21 %) and IC-561715 (2.26 %) recorded higher chlorophyll content than the best check Arka Lohit (2.17 %), and IC-561723 (2.17 %) recorded equal value with this check.

Figure 6: Chlorophyll content (%) of 40 chilli genotypes.

The character-wise top-performing genotypes along with check varietal values of the respective traits of chilli are presented in Table 5.

Table 5: Character-wise top 4 performing germplasm of chilli for yield and quality traits

Average fruit weight (g)	IC-561614 (15.03 g)	LCA-334 (6.20 g)
	EC-596940 (13.30 g)	
	IC-561619 (13.41 g)	
	IC-561715 (13.29 g)	
Fruit length (cm)	EC-596940 (13.70 cm)	Pusa Jwala (11.60 cm)
	IC-561679 (12.63 cm)	
	EC-391083 (12.60 cm)	
	EC-599969 (11.67 cm)	
Fruit diameter (cm)	IC-561619 (2.16 cm)	LCA-334 (1.20 cm)
	IC-561723 (2.06 cm)	
	IC-561694 (2.03 cm)	
	EC-596940 (1.86 cm)	
Number of fruits per plant	IC-278055 (91.33)	LCA-334 (65.33)
	IC-394731(66.33)	
	IC-561670 (65.00)	
Fruit yield per plant (kg/plant)	EC-596940 (0.439 kg)	LCA-334 (0.405 kg)
	IC-278055 (0.417 kg)	
	IC-561614 (0.406 kg)	

Fruit yield per hectare (kg/ha)	EC-596940 (21933.3 kg)	LCA-334 (20266.6 kg)
	IC-278055 (20833.3 kg)	
	IC-561614 (20283.3 kg)	
Ascorbic acid content (mg/100 g)	IC-561670 (134.01 mg/100 g)	Arka Lohit (126 mg
	IC-561614 (129.55 mg/100 g)	/100 g)
	IC-561640 (128.34 mg/100 g)	
	IC-526432 (127.32 mg/100 g)	
	IC-561673 (0.58 %)	
Capsaicin content (%)	IC-561619 (0.53 %)	LCA-334 (0.35 %)
	IC-561715 (0.51 %)	
	IC-526432 (0.49 %)	
	IC-394731 (0.45 %)	
	IC-561691 (0.39 %)	
Capsanthin(ASTA units)	IC-208534 (358.67)	Arka Lohit (290.00
	IC-330193 (328.00)	ASTA units)
	IC-561619 (314.66)	
	IC-335340 (309.00)	
	EC-596940 (297.33)	
	EC-628901 (2.32 %)	
Chlorophyll of green fruits (%)	IC-528876 (2.29 %)	Arka Lohit (2.17 %)
	IC-561715 (2.26 %)	
	IC-284474 (2.24 %)	
	IC-335340 (2.20 %)	
	IC-526432 (2.19 %)	

4. Discussion

Chilli is a commercial crop of vegetable and spice importance. For realizing net profits in its cultivation, the varieties with higher yields accompanied with quality traits have added advantage. Not many released varieties with assured and high-quality characteristics like ascorbic acid, chlorophyll, capsaicin and capsanthin are available to fetch better prices for farmers and are appreciated by the consumers. Especially, the green chillies due to their richer values for ascorbic acid and chlorophyll content are getting more appreciation. The development of exclusive green chilli varieties with the above qualities is the need of the hour. The performance of the new plant genetic resources for the desired traits will result in the identification of superior varieties for commercial cultivation. Analysis of variance for the important character, yield, its attributes and quality were analyzed and were recorded as significant for genotypes for 10 characters of chilli studied in the research including ascorbic acid, chlorophyll of green chilli, capsanthin and capsaicin. The values registered were highest for per hectare chilli fruit yield followed by capsanthin, ascorbic acid, number of fruits per plant, average weight of green fruit and length of the fruit indicating that the genotypes under investigation were different statistically from each other and they are genetically different the error due to replications is non-contributing. The relevant data result of the *per se* performance of 40 genetic resources for 10 traits concluded EC-596940 as superior for yield including, especially, average chilli fresh fruit weight (13.3 g), per plant fresh chilli fruit yield (0.439 kg) and per hectare fresh chilli fruit yield (21933.3 kg).

The results also suggested that, of 40 genetic resources of chilli for ten traits, EC-596940 was superior, in which average fresh weight of fruits, per plant fresh chilli fruit yield and per hectare fresh chilli fruit yield contributed positively. In general, the range of variation was wide for per plant chilli fruit yield, per hectare fruit yield, and average weight of fruits. The present results are in line with those reports of Arya and Saini (1977); Deshpande and Anand (1988); Amarchandra *et al.* (1990); Giritammannavar (1995); Bhatt and Deepak (1996); Kohli and Chatterjee (2000); Ramesh (2001); Geleta and Labuschagne (2004).

Genotypes, EC-566920, IC-447065, IC-526432, IC-561614, IC-561640, IC-561670, IC-561673, IC-561688, IC-561695, Arka Lohit, LCA-334 and Pusa Jwala for ascorbic acid; EC-391083, EC-402105, EC-596940, IC-208534, IC-330193, IC-335340, IC-561619, IC-561694 and Arka Lohit for capsanthin; IC-278055, IC-394731, IC-526432, IC-561619, IC-561673, IC-561715 for capsaicin and EC-378635, EC-391083, EC-566920, IC-284474, IC-335340, IC-526432, IC-561670, IC-561688, IC-561695, IC-561715, IC-561723 and Arka Lohit for chlorophyll, and are traits of potential importance

for further improvement of the respective characters. In general, the range of variation was wide for ascorbic acid, capsaicin and chlorophyll contents. These results give a wider scope for further exploitation of these traits on a commercial scale in chilli. The results are in line with the reports of Mini and Khader (2004); Sood *et al.* (2006); Smitha and Basavaraja (2006); Singh and Yadav (2008); Mishra *et al.* (2001); Dixita *et al.* (2015). Hence, for commercial exploitation of yield, the genetic resources identified in the investigation along with good yield contributors are to be given preference, while new varieties are aimed to be developed in chilli.

The development of any straight variety or hybrid combination, demands the presence of additive genes and non-additive genes, respectively, for their fullest exploitation of genetic potential. Whereas, monogenic or digenic genes conditioned traits are easy to transfer to other genetic backgrounds or to inherit by the next generation through open-pollinated varieties and are responding to the selection pressure. In chilli, of the quality traits of commercial importance, ascorbic acid, chlorophyll, capsaicin and capsanthin are preferred by consumers. The investigation attempted in this area revealed that genotype IC-561670 is superior for commercial exploitation of ascorbic acid (134.01 mg/100 g). For higher capsanthin levels (358.67 ASTA units), genotype IC-208534, whereas to consider higher chlorophyll levels (2.32 %), EC-628901 are the potential chilli genetic resources identified to use. Genotype IC-561673 was found superior for capsaicin content (0.58 %) over other entries and checks. Acharya *et al*. (2007) assessed the variation of 26 chilli entries for 24 characters, which showed similar kind of results. Correlation coefficients were positive and significant for capsaicin and total soluble solids at the mature green stage, and red ripe stage as well. Only, chlorophyll and TSS were positively correlated at the mature green stage stage of the chilli genotypes, phenotypically and genotypically. Some of the researchers reported similar kind of results to the present finding, such as Pallerla Saisupriya *et al*. (2021), who presented that ascorbic acid content was highest in mature green fruit, while carotenoid content was higher in red ripe fruit. The present conclusions are also in line with those reported in chilli by Giritammannavar and Patil (2006); Krishnamurthy *et al.,* (2013); Maneet *et al*. (2015); Shiva *et al.* (2015); Maurya *et al*. (2017); Mamtha *et al.* (2017); Manoj *et al*. (2018). It indicates that direct selection based on these characteristics would be effective for increasing the yield. Janaki *et al*. (2015) reported that considering diversity patterns and horticultural performance, the genotypes Warangal chapata, LCA-702, LCA-724, LCA756, LCA-353 and LCA-716 were identified as promising parents. In similar lines, IC-561670 for ascorbic acid, IC-208534 for capsanthin content and IC-561673 for capsaicin are the best germplasm based on estimates from the current studies.

5. Conclusion

From a practical standpoint from the results obtained, future thrust can be laid on chili crop improvement programs. Considering the mean performance, three superior genotypes for fruit yield, *viz*., EC-596940 (21933.3 kg), IC-278055 (20833.3 kg), and IC-561614 (20283.3 kg) can be released as pure lines or varieties after evaluating in multi-location trials for their use in further hybridization programs. IC-561670 for ascorbic acid (134.01 mg/100 g), IC-208534 for capsanthin content (358.67 ASTA units) and IC-561673 for capsaicin (0.58 %) were identified as superior among the studied germplasm and can be potential sources of quality in pedigree-based selection for chilli varietal improvement. Extensive breeding work to improve the genotypes producing stable capsanthin to the extent of more than 150 ASTA units and a necessary breeding program to improve the yield of chilli should be taken up.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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