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RESEARCH ARTICLE

Genetic Diversity in Indian Landraces of Cucumber (*Cucumis sativus* L.) Based on Morpho-Horticultural Traits

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Until recently, the main focus of breeding programmes in cucumber (*Cucumis sativus* L.) was the development of varieties and hybrids for high yield. However, consumer preference of cucumber is mainly determined by the qualitative traits of the fruit namely colour, shape, size, tenderness, crispness, texture and organoleptic qualities. In this study, observations on 15 qualitative traits, three major quantitative traits, storage characters and organoleptic attributes were recorded in 53 cucumber accessions, collected from 12 Indian states. The skin colour of the tender fruits ranged from light green, green, dark green to cream and fruit shapes of elliptical elongate, oblong ellipsoid and globular were observed. Ten accessions exhibited orange coloured flesh during the ripe stage of the fruit, indicating carotenoid content in the flesh. Shelf life of 4-6 days was exhibited by IC331627, IC613481, IC613461, IC202058A, IC331619, IC613460, IC613477 and IC613478 with a weight loss of less than 10 g during storage under room temperature. Four accessions namely IC613480, IC613481, IC618084A and IC613484 exhibited organoleptic qualities better than the control variety, AAUC-2. Based on the multivariate analysis using PCA, fruit skin colour and texture were identified as the most discriminating qualitative traits explaining greater variability in cucumber. Elliptical elongate shape with green or light green colour of the fruits are the most common and preferred characters for commercial cucumber varieties. IC613481 and IC613480, both collections from West Bengal ranked superior with respect to organoleptic scoring, preferable storage qualities and promising yield attributes. Systematic characterization of the genotypes revealed that they are potential sources of genetic variability, worth harnessing through improvement programmes.

Key Words: Cucumber, *Cucumis sativus,* Consumer preference, Genetic diversity, Organoleptic quality

Introduction

Cucumber is an indigenous vegetable of India (Sebastian *et al*., 2010). In all probability, it originated in the foothills of the Himalayas. The two botanical varieties, namely the domesticated cucumber, *Cucumis sativus* var. *sativus* L. and the wild cucumber *C. sativus* var. *hardwickii* (Royle) Alef. are ubiquitously found distributed in this region (Lv *et al*., 2012). Wide genetic variability is likely to occur among cucumber genotypes from this region. The neighbouring China is considered as the secondary centre of diversity (Valcarcel *et al.*, 2018). The dissemination of cucumber from India to other regions afar occurred very early. The crop is presently being grown on a large-scale even in temperate zones under controlled environment like glass house.

Often, populations derived from adapted or improved breeding lines that possess a narrow genetic base have been used commonly in cucumber improvement programmes. Hence, selection as well as population improvement within the adapted material is unlikely to yield the expected return (Kumar *et al*., 2017). The landrace population with a relatively high degree of genetic variability, however is likely to be more advantageous than the improved varieties. A landrace is a locally adapted variety evolved from a variable population as a result of natural selection and shaped according to the choice of local people. Consumer preference in cucumber is mainly determined by the colour, shape, texture and organoleptic qualities of fruits. Although scarce, studies on inheritance pattern of these

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characters in cucumber have been reviewed long before by Poole (1944). These visually assessable morphological characters are the preferred choice for diversity studies, as these are among the easiest morphological markers used in germplasm management (Stanton *et al.,* 1994).

It is well-known that progenies derived from geographically and genetically diverse parents in the hybridization programme would prove advantageous in terms of their agronomic performance owing to the diversity in genetic makeup. The landraces constitute a valuable resource for cucumber breeders to increase variability concerning qualitative and quantitatively inherited characters and adaptation to specific growing conditions (Valcarcel *et al.*, 2018). Thus, inclusion of landraces, un-adapted and exotic lines in breeding population may result in improved varieties with desirable combination of characters.

North-eastern India characterized by the transition zone between the Indian, Indo-Malayan and Indo-Chinese biogeographic regions is enriched with diverse genetic resources, particularly of cucurbitaceous vegetables (Ranjan *et al*., 2019). In addition, these landraces being cultivated and maintained as open pollinated populations by the local farming community for generations, has contributed considerably to the variability observed in the population. Hence, the present study was undertaken to asses qualitative (15) and quantitative (3) traits in 53 accessions of cucumber collected from 12 states of India. Hence, systematic characterization and evaluation of these genotypes is essential to delineate their genetic potential.

Materials and Methods

The experimental materials consisted of 53 landraces of cucumber procured from the National Gene bank at ICAR-National Bureau of Plant Genetic Resources, New Delhi (Table 1). This collection largely comprised of local landraces grown by the tribal population of North-eastern states of India namely Tripura (8), Mizoram (14), Nagaland (1) and Arunachal Pradesh (4). It also included accessions from other agro-ecological zones *viz.,* Kerala (1), Karnataka (1), Maharashtra (2), West Bengal (12), Himachal Pradesh (1), Andaman and Nicobar Islands (3), Uttarakhand (2) and Odisha (1)

The experiment was laid out during June-Aug 2015 at the experimental farm of ICAR-NBPGR, Regional Station, Thrissur (10.5480^{o} N, 76.2830^{o} E) following an augmented block design with three control varieties, namely AAUC-2 (Assam Agricultural University Cucumber-2, a variety released from Assam Agricultural University, India), Swarna Agethi (variety released from ICAR-Research Complex for Eastern Region, Patna, Bihar, India) and Poinsette (an exotic collection). The mean annual temperature and rainfall in the region were 27.2^{o}C and 2639.4 mm, respectively. Each accession was represented by ten direct seeded plants raised at a spacing of 0.50 × 1.50 m in a row of 4.5 m length. The package of practice recommendations of KAU (2011) was followed for raising a good crop. As the soils were in the acidic pH range, lime was applied @ 600kg/ha as a pre-sowing treatment. The plots were hand weeded to avoid weed growth.

Observations on 15 qualitative characters pertaining to the leaf (3), plant habit (1), stem (1), flowers (2) and fruit (8) were recorded based on the minimal descriptor list developed by ICAR-NBPGR (2001) as illustrated in Table 2. Trait variability distribution was graphically depicted in pie diagrams. Principal component analysis was done using an online trial version of Minitab software. Single fruit weight, length and width, the shelf life attributes were the quantitative traits recorded. Shelf life of fruits was estimated by measuring the loss of weight of the fresh fruits and number of days of storage assessed as discolouration of the fruit skin upon storage at room temperature.

Sensory evaluation of the tender fruits from each accession was done immediately after harvest by a 15 member judging panel. Score-card for bitterness, crispness and flavour was prepared and each quality attribute was scored using a five point hedonic scale which ranged from zero to five. The mean score for each quality attribute for individual genotypes were computed over the data recorded by the judging panel. To represent the acceptability of the fruit in terms of bitterness, the complement (maximum score - average score) with respect to maximum score was taken. This exercise was done in order to maintain uniformity in reading the score in ascending order. Kendall's coefficient of concordance was employed to study the significance of perception of taste between the individuals as well as to help rank the accessions based on mean rank of different sensory attributes analysed. The hedonic scales were then converted to rank scores and rank analysis was done by Kendall's coefficient of concordance (Siegel, 1956).

Table 1. Landraces with their passport data used in the study

S. No	Collector No.	Accession No.	Genus	Species	State	Latitude	Longitude
1	JS/06-01	IC541367	*Cucumis*	*sativus*	A&N Islands	12.229	92.809
2	JS/06-25	IC541391	*Cucumis*	*sativus*	A&N Islands	12.508	92.932
3	MS/05-12	IC539818	*Cucumis*	*sativus*	A&N Islands	12.654	92.899
4	JB/12-203	IC613471	*Cucumis*	*sativus*	Arunachal Pradesh	27.158	95.569
5	JB/12-217	IC613472	*Cucumis*	*sativus*	Arunachal Pradesh	27.299	96.148
6	JB/12-236	IC613473	*Cucumis*	*sativus*	Arunachal Pradesh	27.086	95.442
7	JB-12-183A	IC618084A	*Cucumis*	*sativus*	Arunachal Pradesh	27.176	96.078
8	BB-11/2001A	IC331619	*Cucumis*	*sativus var. hardwickii*	Himachal Pradesh	30.905	77.097
9	JR-04-13	IC469517	*Cucumis*	*sativus*	Karnataka	12.763	76.060
10	JJK/10-601	IC595518	*Cucumis*	*sativus*	Kerala	9.684	76.337
11	BBL-67/2000	IC277048	*Cucumis*	*sativus var. hardwickii*	Maharashtra	17.248	73.371
12	BBL-49/2000	IC277030	*Cucumis*	*sativus var. hardwickii*	Maharashtra	18.516	73.182
13	JB-11/18	IC613457	*Cucumis*	*sativus*	Mizoram	23.545	92.442
14	JB-11/28	IC595504	*Cucumis*	*sativus*	Mizoram	24.150	92.384
15	JB-11/34	IC613458	*Cucumis*	*sativus*	Mizoram	24.150	92.384
16	JB-11/43	IC595505	*Cucumis*	*sativus*	Mizoram	24.102	92.342
17	JB-11/60	IC613459	*Cucumis*	*sativus*	Mizoram	24.145	92.405
18	JB-11/69	IC612081	*Cucumis*	*sativus*	Mizoram	24.185	92.422
19	JB-11/75	IC613461	*Cucumis*	*sativus*	Mizoram	24.236	92.431
20	JB-11/91	IC613462	*Cucumis*	*sativus*	Mizoram	24.224	92.431
21	JB-11/99	IC612082	*Cucumis*	*sativus*	Mizoram	24.011	92.403
22	JB-11/120	IC613465	*Cucumis*	*sativus*	Mizoram	23.145	92.405
23	JB-11/126	IC613466	*Cucumis*	*sativus*	Mizoram	23.154	92.384
24	JB-11/128	IC613467	*Cucumis*	*sativus*	Mizoram	23.154	92.384
25	JB-11/145	IC613488	*Cucumis*	*sativus*	Mizoram	23.224	92.431
26	JB/11-71	IC613460	*Cucumis*	*sativus*	Mizoram	24.185	92.422
27	KPAC-1494	IC613474	*Cucumis*	*sativus*	Nagaland	26.760	95.610
28	BBD-12/2001	IC331445	*Cucumis*	*sativus*	Odisha	18.856	82.735
29	JB/11-182-A	IC595508A	*Cucumis*	*sativus*	Tripura	23.084	91.364
30	JB/11-205	IC595510	*Cucumis*	*sativus*	Tripura	23.025	91.541
31	JB/11-206	IC618083	*Cucumis*	*sativus*	Tripura	23.025	91.541
32	JB/11-217	IC595512	*Cucumis*	*sativus*	Tripura	23.262	91.346
33	JB/11-229	IC595514	*Cucumis*	*sativus*	Tripura	24.012	91.381
34	JB/11-242	IC595515	*Cucumis*	*sativus*	Tripura	23.482	91.535
35	JB/11-262	IC595517	*Cucumis*	*sativus*	Tripura	23.545	91.502
36	JB/11-197	IC613470	*Cucumis*	*sativus*	Tripura	23.005	91.546
37	BB-19/2001A	IC331627	*Cucumis*	*sativus var. hardwickii*	Uttarakhand	30.317	78.032
38	U38/IS/AD/36	IC202058A	*Cucumis*	*sativus var. hardwickii*	Uttarakhand	30.317	78.032
39	SKYAC/239	IC613470	*Cucumis*	*sativus*	West Bengal	22.370	88.090
40	SKYAC/244	IC613475	*Cucumis*	*sativus*	West Bengal	22.900	88.300
41	SKYAC/247	IC613476	*Cucumis*	*sativus*	West Bengal	22.900	88.300
42	SKYAC/251	IC613477	*Cucumis*	*sativus*	West Bengal	22.900	88.300
43	SKYAC/253	IC613478	*Cucumis*	*sativus*	West Bengal	22.900	88.300
44	SKYAC/262	IC613479	*Cucumis*	*sativus*	West Bengal	22.940	88.230
45	SKYAC/265	IC613480	*Cucumis*	*sativus*	West Bengal	22.940	88.230
46	SKYAC/270	IC613481	*Cucumis*	*sativus*	West Bengal	23.070	88.590
47	SKYAC/295	IC613482	*Cucumis*	*sativus*	West Bengal	22.950	88.610
48	SKYAC/314	IC613483	*Cucumis*	*sativus*	West Bengal	23.050	88.700
49	SKYAC/316	IC613484	*Cucumis*	*sativus*	West Bengal	22.960	88.720
50	SKYAC/319	IC613485	*Cucumis*	*sativus*	West Bengal	22.990	88.820

Table 2. Descriptors and descriptor states for the 15 qualitative characters studied

Characters	Descriptor states and the respective scores								
Leaf shape	1-Cordate	2-Oblong	3-Ovate	4-Ovovate	5-Reniform	99-Others			
Leaf pubescence density	1-No hairs	2-Sparse	3-Intermediate	4-Dense	99-Others				
Leaf margin	1-Unifid	2-Bifid	3-Multifid	99-Others (Angular)					
Fruit skin colour	1-Cream	2-Yellow	3-Liht green	4-Green	5-Dark green	6-Orange	7-Pink	8-Brown	99-Others
Fruit shape	1-Elliptical elongate	2-Oblong ellipsoid	3-Globular (round)	4-Stem end tapered	5-Blossom end tapered	99-Others			
Fruit Flesh colour	1-White	2-Green	3-Yellow	4-Orange	99-Others (light green)				
Stem end fruit shape	1-Depressed	3-Flattened	5-Rounded	7-Pointed	99-Others				
Blossom end fruit shape	1-Depressed	3-Flattened	5-Rounded	7-Pointed	99-Others				
Fruit skin texture	1-Plain	2-Netted	3-Rough	99-Others					
Presence of seed cavity	0-Absent	1-Present							
Colour of tender fruits at 3 DAA	1-Cream	2-Yellow	3-Liht green	4-Green	5-Dark green	6-Orange	7-Pink	8-Brown	99-Others
Plant growth habit	3-Short viny	5-Medium viny	7-Long viny	99-Others					
Stem pubescence	0-Absent	1-Present							
Sex type	1-Monoecious	2-Gymno-monoecious	3-Andro-monoecious	4-Gyno Andro-monoecious	5- Androecious	6-Gynoecious	99-Others		
Flower colour	1-White	2-Cream	3-Yellow	4-Orange	99-Others				

Scoring for downy mildew disease caused by *Pseudoperonospora cubensis* was undertaken on the 60th day after sowing to assess the tolerance level of the accessions. The intensity of downy mildew disease was assessed with the score chart from 0 to 5 scale (0 - no infection; 1 - 0 to10 %; 2 - 10.1 to15 %; 3 - 15.1 to 25 %; 4 - 25.1 to 50 % and 5 - more than 50 percent of leaf area being covered with mildew growth) as described by Jamadar and Desai (1997). The per cent disease index of downy mildew was calculated using the formula given by McKinney (1923).

The seeds of these landraces were multiplied by selfing/ sibmating and conserved in National Genebank, New Delhi for long term storage and in Medium Term Storage (MTS) facility at Regional Station, Thrissur, for supply to farmers and breeder/researchers.

Results and Discussion

The scores and data recorded for both qualitative and quantitative traits respectively, are depicted in Table 3. The accessions exhibited no variability with regard to a few plant, leaf, floral and fruit characters. All accessions had a long viny growth habit with dense stem pubescence irrespective of their origin. Shape, pubescence density and margin of leaf, stem end and blossom end shape of the fruit also did not vary between accessions. The leaves were densely pubescent and the leaf shape was found to be cordate with angular margins in all the accessions. The vines produced yellow male and female flowers with majority of them being five petallate, while a few flowers possessed 6-8 petals. Fruits possessed flattened shape both at stem end and blossom end. Occasionally, fruits with depressed shape at stem end as well as blossom end were observed, but at a very low frequency. Esteras *et al*. (2008) had, however observed high variation among stem end and blossom end shape of cucumber fruits.

The characteristics that affect the marketability of cucumber are decided by four main attributes. They are colour and appearance, flavour (taste and aroma), texture and nutritional value in the order specified (Barrett *et al.*, 2010). Among the 53 genotypes, seven (IC613457, IC613475, IC277048, IC277030, IC202058A, IC613462 and IC595518) possessed cream/ivory coloured fruits (Fig. 1). The major fruit skin colour observed was light green followed by green. IC595505, IC613459 and Poinsette exhibited dark green colour. Rich diversity for exterior fruit colour (cream, pale green, dark green, yellow to vibrant orange with dark green streaks) among different cultivars in cucumber was also reported by

Table 3. Observations on qualitative and quantitative characters in 53 cucumber landraces

S.No.	Accessions	FSC	FS	FFC	BEFS	FST	PSC	CTF	FL/FD ratio	PDI (%)	SFW (g)	LWDS (g)	NDS
		Qualitative characters							Quantitative characters				
1	IC613457	1	2	1	3	2	0	1	2.97	74.5	268.04	19.04	6.39
2	IC595504	3	1	1	3	3	0	4	3.47	70.5	236.04	19.04	6.19
3	IC613458	4	1	99	3	3	0	5	3.85	48.5	303.04	16.04	5.99
4	IC595505	5	1	99	3	3	1	3	2.89	66.5	259.04	12.04	5.79
5	IC613459	5	2	2	3	3	0	5	2.08	80.5	180.04	12.04	6.19
6	IC612081	4	2	1	3	3	0	4	2.68	88.5	210.04	20.04	5.99
7	IC613461	3	2	99	3	3	0	3	2.95	78.5	256.04	9.04	4.19
8	IC613462	1	2	1	3	2	0	3	2.67	83.17	281.38	19.71	6.06
9	IC612082	3	2	1	3	2	0	3	2.16	89.17	234.38	11.71	4.26
10	IC613465	3	2	99	3	2	1	3	2.76	77.17	274.38	18.71	5.86
11	IC613466	3	1	1	3	3	1	3	3.58	79.17	273.38	20.71	5.46
12	IC613467	3	2	1	3	2	0	3	2.52	83.17	283.38	16.71	6.06
13	IC613488	3	2	1	3	2	0	3	2.59	63.17	292.38	13.71	6.21
14	IC595508A	4	2	1	3	3	0	3	2.20	59.17	176.38	11.71	4.39
15	IC613460	3	2	1	3	2	0	3	2.91	47.17	234.38	9.71	4.79
16	IC595510	4	1	99	3	3	0	4	4.21	69.17	282.38	16.71	5.59
17	IC618083	4	2	99	3	3	1	3	2.68	53.17	265.38	14.71	5.19
18	IC595512	4	2	1	3	3	0	3	3.06	65.17	168.38	20.71	5.79
19	IC595514	3	1	1	3	3	0	3	3.50	53.17	163.38	17.71	4.79
20	IC595515	4	2	1	3	3	0	3	1.85	55.17	273.38	13.71	5.99
21	IC595517	3	1	1	3	3	1	3	4.33	59.17	176.04	16.38	5.66
22	IC613471	3	2	1	5	2	0	4	2.77	69.17	304.04	15.38	6.06
23	IC613472	3	1	1	3	2	0	3	3.51	59.17	343.04	15.38	4.86
24	IC613473	3	1	1	3	3	0	3	3.89	41.17	282.04	20.38	5.46
25	IC624255	4	1	1	3	3	0	3	3.89	63.17	316.04	19.38	6.66
26	IC613475	1	1	1	3	3	0	4	4.00	55.17	223.04	12.38	4.66
27	IC613476	3	2	1	3	3	0	3	3.50	54.5	191.71	12.71	4.99
28	IC613477	4	1	1	3	3	0	3	3.16	22.5	219.71	9.71	5.39
29	IC613478	3	1	1	3	3	0	3	3.55	52.5	191.71	9.71	4.99
30	IC613479	4	1	1	3	3	0	3	3.84	34.5	269.71	4.71	3.99
31	IC613480	3	1	1	3	3	0	3	3.42	36.5	159.71	13.71	4.59
32	IC613481	3	1	1	3	3	0	3	3.42	48.5	238.71	8.71	4.79
33	IC613482	3	1	1	3	3	0	3	3.42	42.5	216.71	13.71	5.19
34	IC613483	4	1	1	3	3	1	3	3.66	30.5	205.38	16.04	4.66
35	IC613484	3	1	1	3	2	0	3	3.48	52.5	194.38	12.04	4.46
36	IC613485	3	1	1	3	3	0	3	3.08	62.5	225.38	10.04	4.66
37	IC613474	4	1	1	3	3	0	3	3.11	66.5	183.38	14.04	4.26
38	IC595518	1	2	1	3	3	0	1	2.73	18.5	321.38	17.04	4.46
39	IC618084A	4	1	1	3	3	0	3	3.35	62.5	238.38	12.04	3.66
40	IC331445	3	1	1	7	3	1	3	3.58	56.5	218.38	14.04	4.06
41	IC331627	4	3	2	3	1	0	3	1.20	61.17	32.97	8.38	6.06
42	IC277048	1	3	1	3	1	0	3	1.10	59.17	73.38	10.38	6.26
43	IC331619	3	2	99	3	1	0	3	1.58	45.17	81.38	9.38	6.26
44	IC541367	3	2	99	3	3	1	3	2.79	79.17	208.38	18.38	5.86
45	IC541391	4	1	2	3	3	0	3	4.00	71.17	174.38	19.38	5.26
46	IC469517	3	2	1	3	2	0	3	3.29	79.83	312.21	19.04	4.79
47	IC539818	4	1	1	3	2	1	3	3.50	43.83	261.71	15.04	4.19
48	IC277030	1	2	1	3	1	0	3	2.45	45.83	235.71	14.04	6.59
49	IC613470	3	1	1	3	3	0	3	2.69	75.83	198.71	11.04	4.19
50	IC202058-A	1	2	1	3	2	0	3	1.71	85.83	147.71	9.04	5.39
51	AAUC-2	3	1	1	3	3	0	3	3.57	69.5	241.25	15.38	5.45
52	Poinsette	5	1	1	3	2	0	4	3.17	72.75	241.63	14.88	5.13
53	Swarna Agethi	3	1	1	3	3	0	3	3.59	79.25	211.25	14.88	5.00

LS-Leaf shape; LPD-Leaf pubescence density; LM-Leaf margin; FSC-Fruit skin colour; FS-Fruit shape; FFC-Fruit flesh colour; SEFS- Stem end fruit shape; BEFS-Blossom end fruit shape; FST-Fruit skin texture; PSC-Presence of seed cavity; CTF-Colour of tender fruits at 3 DAA; PDI-Percent Disease Index; SFW-Single fruit weight, LWDS-Loss of weight during storage; NDS-Number of days of storage

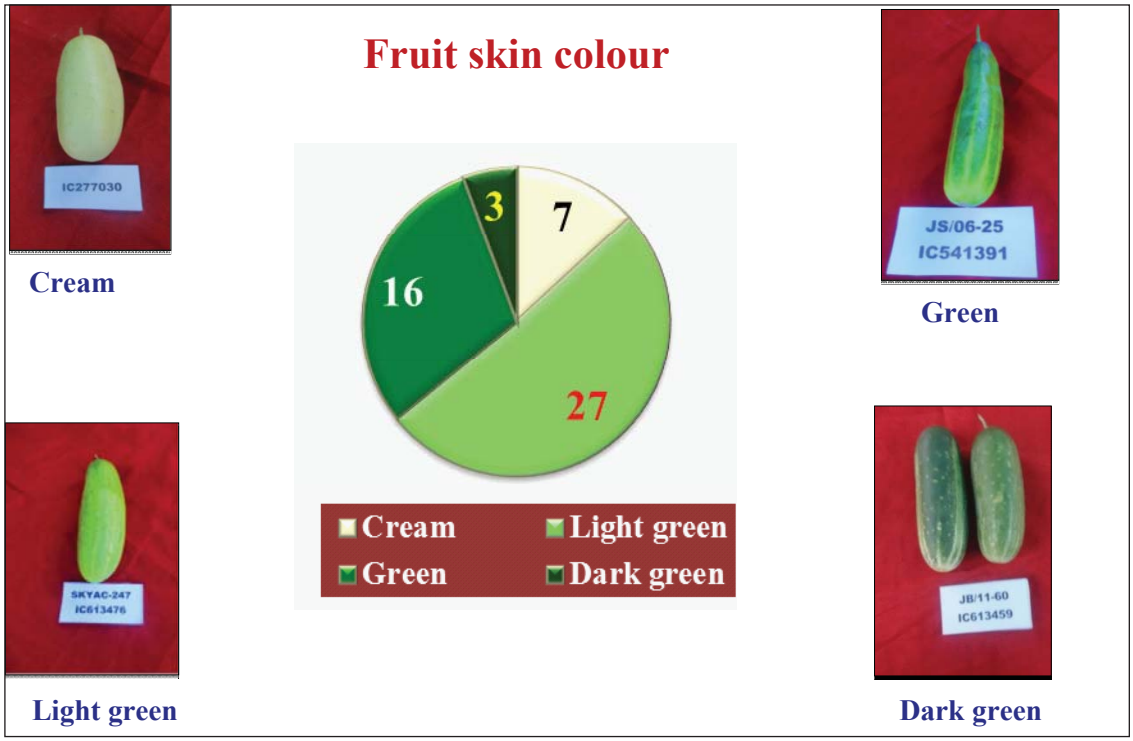


Fig. 1. Variability and frequency distribution of fruit skin colour

Ranjan *et al.* (2019). Liu *et al*. (2015) reported the desirability of white skinned cultivars of cucumber in the Gansu and Shandong province of China. Further, authors have observed that cream/ivory coloured slicing cucumber is the most preferred type in Hassan district and adjoining belt in Karnataka state of India. Cream coloured cucumbers will be a novel type, as most of the released varieties possess green to dark green skin colour. Hutchins (1940) reported that the fruit colour in cucumber is controlled by two genes *RC* versus *rc* with an inheritance ratio of 9 red fruit colour (*RC*): 3 orange (*Rc*): 3 yellow (*rC*): 1 cream (*rc*) colour. Similarly, white immature skin colour (*w*) was found to be recessive to the normal green (Cochran, 1938), and yellow green (*yg*) recessive to dark green and epistatic with light green (Youngner, 1952).

Fruit shapes of elliptical elongate, oblong ellipsoid and globular were observed. Elliptical elongate shape is the highly preferred one, as this shape gives maximum slices per fruit for salad purpose. Oblong ellipsoid shaped fruits were produced by 22 genotypes (41.05 per cent) whereas only two accessions (IC331627 and IC277048) exhibited globular/round shape (Fig. 2). Tiedjens (1928) in cucumber reported that environment has a profound effect on the shape and size of mature fruits in cucumber. Fruit length is also an important agronomic trait that affects yield and product appearance. It varied from 5 cm to 60 cm in different cucumber cultivars (Zhao *et al*, 2019). The length/diameter ratio (L/D) of pickling cucumber fruit is also important in the cucumber processing industry (Tolla, 1985). The length to diameter ratio of fruits determines the shape of the fruit. In the present study majority of the elliptical elongated fruits exhibited a length to breadth ratio greater than 3.00, the exception being IC613470 and IC595505. IC613470 produced comparatively small fruits with an average length of 12.67 cm, breadth of 4.71 cm and a length to diameter ratio of 2.69. Similarly, oblong ellipsoid fruits exhibited fruit length to breadth ratio of less than 3.00 except in IC613476 (3.50), IC469517 (3.29) and IC595512 (3.06). Single fruit weight ranged from 32.97 g (IC331627) to 343.04 g (IC613472). The fruit shape was round (length to breadth ratio: 1.20) in the former, while, it was elliptical elongate shape in the latter. Poinsette (241.63 g) recorded the highest value for the single fruit weight among checks. Fruit length, diameter and fruit weight are generally considered as

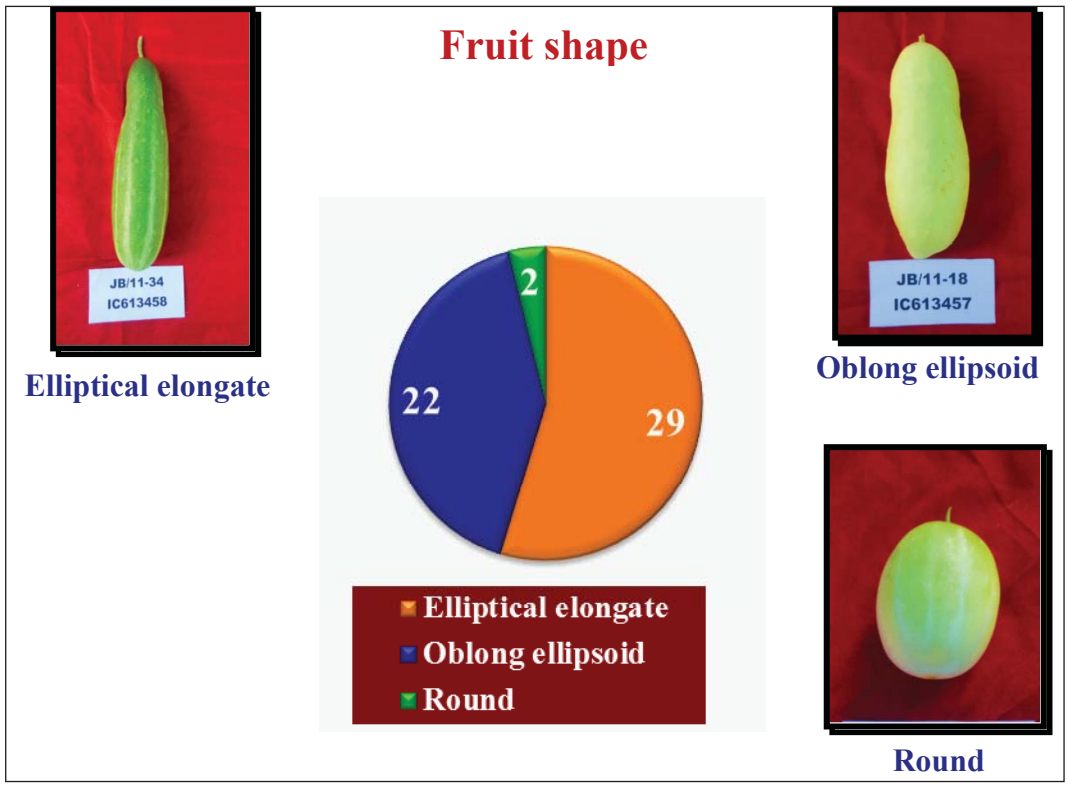


Fig. 2. Variability and frequency distribution of fruit shape

the most important yield contributing characters (Khan *et al*., 2015).

Forty two accessions (79%) registered white coloured flesh, whereas light green flesh was exhibited by eight (15%) accessions. Three genotypes possessed green fleshed fruits (IC331627, IC613459 and IC541391) (Fig. 3). Similar results of wide variability in flesh colour in cucumber (intense white, dingy white, light green, yellow to intense orange) were reported by Ranjan *et al*. (2019). Ten accessions namely IC595515, IC613467, IC613464, IC613471, IC613472, IC613461, IC595514, IC618084A, IC595508A and IC613463 exhibited orange coloured flesh of the fully ripe fruit, indicating the presence of carotenoids in the flesh (Fig. 4). Cochran (1938) reported that two alleles of a gene *viz*., cream (*W*) and white (*w*) control the flesh colour inheritance in cucumber. However, there are few reports on cucumber flesh colour at the molecular level. Shen (2009) identified three quantitative trait loci (QTLs) related to beta-carotene content (bCC4a, bCC4b, and bCC7) and two QTLs related to flesh colour (FCG5 and FCG7). Cucumbers generally lack the pigmentation of mesocarp (flesh) in contrast to other cucurbitaceous fruits. It was reported that a distinct group of cultivars namely Xishuangbanna gourd (*Cucumis sativus* var. *xishuangbannanesis*) from China is the source for high carotenoid content (Qi and Yuan, 1983) for introgression of β-carotene (orange flesh) genes to cucumber (Kumar *et al*., 2017). Lv *et al.* (2012) reported that Xishuangbanna gourd is closely related to cucumber germplasm of Indian origin. Moreover, Ranjan *et al.* (2019) reported the prevalence of diversity of orange fleshed cucumbers in North-eastern region of India. They observed that AZMC-1, a collection from Mizoram, India was found to contain total carotenoids content as high as 54.8 µg/g. These accessions with carotenoid content in the flesh of mature fruit have immense potential in nutraceutical preparations. Variation in skin colour, flesh colour and fruit shape was also reported by Pragathi (2014) in hybrid varieties of cucumber.

Smooth or plain skin is preferred over netted and rough skin of fruits and majority of the accessions exhibited fruits with tubercular skin texture. However, smooth skinned fruit texture was exhibited by four accessions (IC331627, IC277048, IC331619 and IC277030), netted by 14 and rough by 35 accessions (Fig. 5). The difference in skin texture of fruits was due to the persistence of tubercles or the remnant mass of tissues at the sites of tubercles. There are cultivars

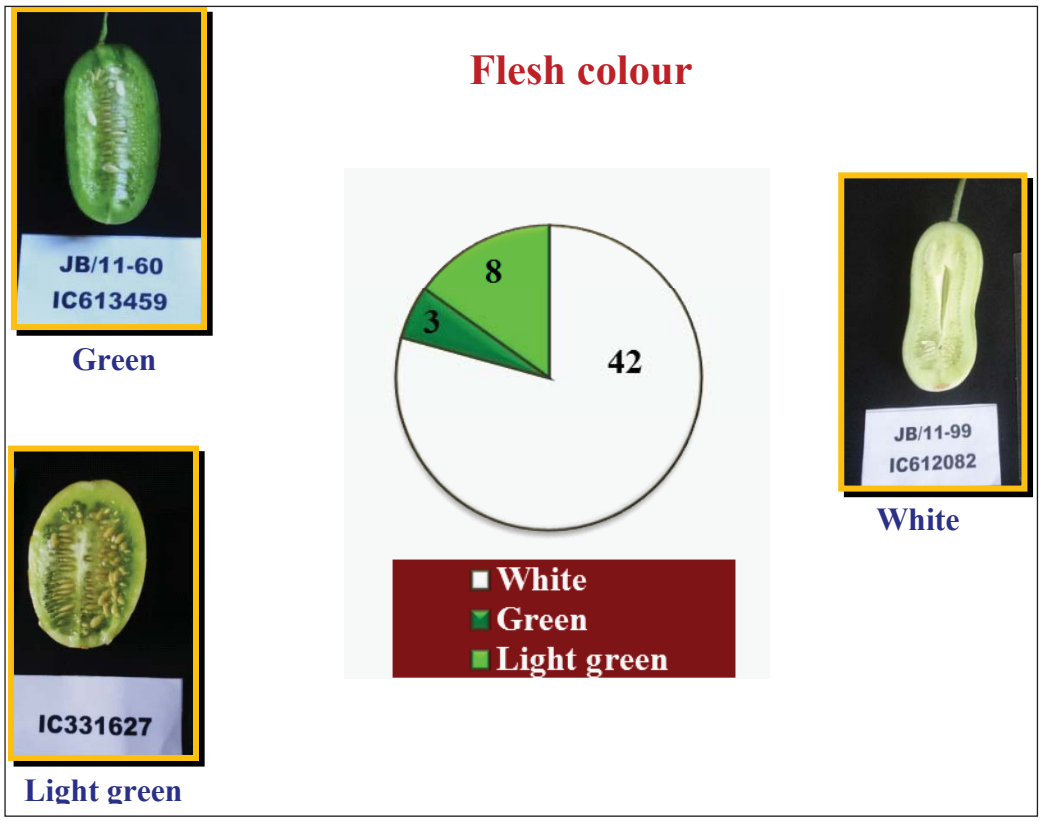


Fig. 3. Variability and frequency distribution of flesh colour

Fig. 4. Landraces with carotenoid content in flesh of ripe fruits

namely 'field cucumber' with prominent black or white spines and 'the greenhouse or forcing cucumber' also called 'English cucumber' with spineless fruit produced parthenocarpically as reported by Ranjan *et al*. (2019). Efforts should be directed to selecting fruits with smooth or plain or glossy skin texture. Thin and tender nature of the fruit skin contributes to its excellent eating quality but causes quick dehydration (Rubatzky and Yamaguchi, 1997). The accessions possessing plain fruit skin texture in the study were of bitter *Cucumis sativus* var. *hardwickii* types bearing globular fruits. Majority of the rough fruited types identified in the study were consumable

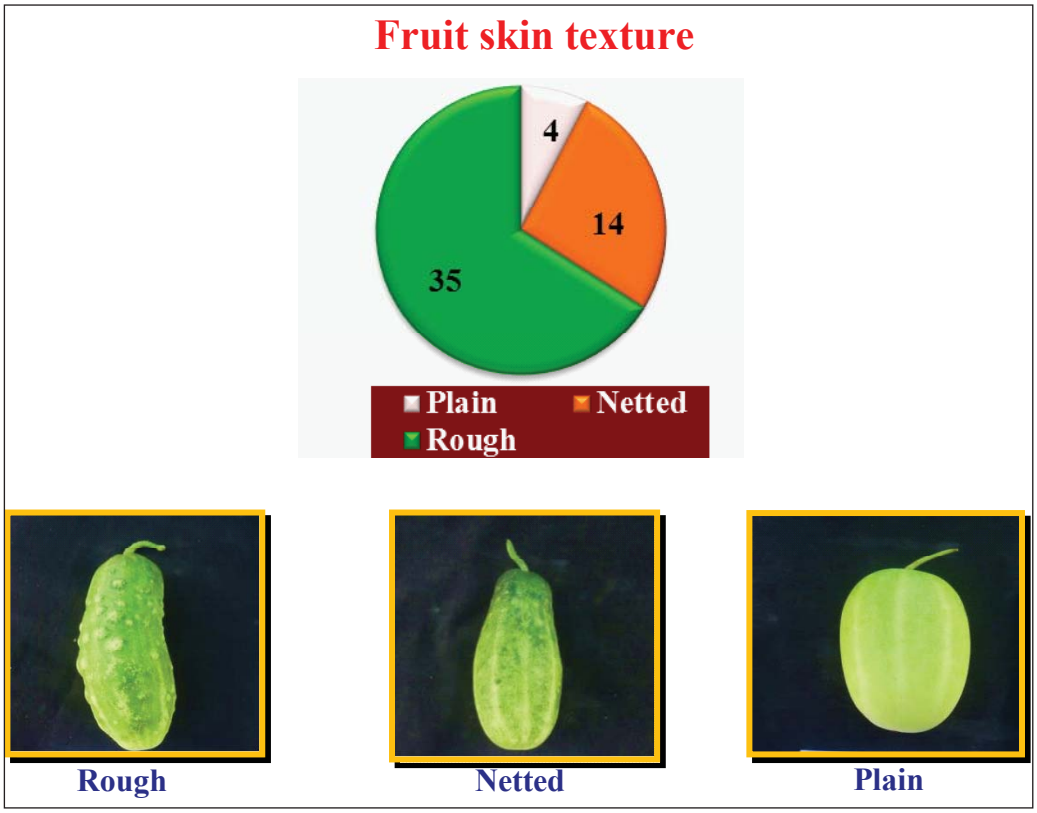


Fig. 5. Variability and frequency distribution of fruit skin

as the tubercles easily shed off during harvest. Rough and spiny fruit skin texture in cucumber genotypes were earlier reported by Zhang *et al.* (2012). In contrast to other qualitative traits, inheritance of characters related to fruit skin texture has been studied by many researchers. Those studies include the coarse spines (*F*) versus fine (*f*) nature of fruit (Hutchins, 1940), black (*B*) versus white (*r*) spines (Cochran, 1938; Hutchins, 1940; Tkachenko, 1935), few (*S*) versus numerous (*s*) spines (Hutchins, 1940), heavy netting (*H*) versus no netting (*h*) on fruits (Hutchins, 1940), spines (*A*) versus no spines (*a*) (Strong, 1931), mottled skin (*M*) versus self-coloured (*m*) (Strong, 1931), dull skin (*G*) versus glossy (*g*) (Strong, 1931), tough skin (*Te*) versus tender skin (*te*) (Strong, 1931), warty skin (*Tu*) versus non-warty (*tu*) (Strong, 1931) and smooth brown (*P*) versus rough yellow (*p*) fruit surface (Tkachenko, 1935).

Forty-four out of the 53 accessions (83%) lacked seed cavity in tender fruits while it was present in the remaining 9 accessions (17%). Seed cavity is not an appealing component as round slices without cavity is more preferred. However, it was noticed that the presence and absence of seed cavity were also influenced by the maturity stage of fruit at the time of harvest. Over maturing of fruits (by 2-3 days) led to development of seed cavity in some of the accessions.

There was wide variability in colour of tender fruits at 3 days after anthesis. The colour ranged from cream, light green, green to dark green. Two accessions *viz*., IC613457 and IC595518, possessed cream colour, whereas, it was green in six accessions *viz*., IC595504, IC612081, IC595510, IC613471, IC613475 and Poinsette and dark green in two accessions *viz*., IC613458 and IC613459. This trait was also influenced by environmental conditions prevailing during the growth period.

Storage studies are very important for maintenance of fresh and wholesome appearance of the fruits. After picking, cucumbers lose their quality gradually owing to the cell destruction and colour variations due to enzymatic reactions (Miano *et al*., 2016). The main deteriorating changes in cucumber during storage and distribution are yellowing of fruits, loss of moisture that leads to shrivelling and physiological injury caused by low temperature (Adamicki, 1985). Storage studies indicated that accessions differed significantly with respect to their storage potential in terms of loss of

weight owing to dehydration over storage as well as their period of marketability. Majority of the accessions developed shrivelled symptoms and discolouration at the stem end within 3-4 days during storage. Similar results were reported by Villata *et al.* (2003) in cucumber. The weight loss during storage ranged from 4.71 g (IC613479) to 20.71 g (IC613466). IC618084 recorded the least days of storage (3.66 days), with a weight loss of 12.04 g upon storage. On an average, the accessions could store up to 5.27 days with a mean weight loss of 14.34 g. It was observed that weight loss was not directly related to the number of days of storage. The accessions possessing less weight loss and more number of storage days are preferred. In the accessions studied, IC331627, IC613481, IC613461, IC202058A, IC331619, IC613460, IC613477 and IC613478 possessed good storability with weight loss of less than 10 g and storage days of 4-6 days.

Downy mildew is a major disease of cucumber in the open field as well as polyhouse conditions. Presently, very few cultivars are reported to be tolerant to this disease. In the present study, the incidence ranged from 18.50 per cent in IC595518 to 89.17 per cent in IC612082. Thirteen accessions recorded less than 50 per cent incidence. It is known that the multiplication and spread of fungus *Pseudoperonospora cubensis* causing downy mildew is highly dependent on the temperature and relative humidity prevailing in the area. As the crop was raised during monsoon season, chance of escape of disease infection was very less. Therefore, accessions that had exhibited tolerance reaction are to be screened further to confirm their tolerance to the pathogen infection.

Tender cucumbers are highly valued for their unique flavour as well as for the crispness of the flesh. Crispness is described as one of the most versatile single texture parameter universally liked by the consumers. In the present study, 29 accessions recorded less bitterness compared to the control variety Poinsette, which was the least bitter among the check varieties used (Table 4). Crispness was highest in the check variety Swarna Agethi. The fruits of three accessions were crispier than Swarna Agethi. The flavour was best expressed in fruits of AAUC-2 among check varieties and nine accessions recorded better values for flavour than AAUC-2. Based on the cumulative organoleptic score, IC613481 ranked first, followed by IC613480, both being collections from West Bengal. AAUC-2 was found to be the most organoleptically superior control variety registering a total score of 96.03. Four accessions namely IC613480, IC613481, IC618084A and IC613484 exhibited organoleptic qualities better than AAUC-2.

Principal component analysis was done using the six qualitative traits which were identified as variable among the accessions. The values of the Eigen-vectors and their contribution to variation are presented in Table 5. The five principal components accounted for 94.10 per cent of the total variance. The first three principal components having Eigen values more than 1.00 accounted for 76.40 per cent of variability. The first principal component (PC1) with an Eigen value of 2.084 corroborated for 34.70 per cent of total variance, and exhibited high contributing factor loadings from fruit skin colour (0.524), fruit skin texture (0.514), colour of tender fruits harvested at 3 days after anthesis (0.352), presence of seed cavity (0.253) and flesh colour (0.207), revealing the correlation of PC1 with these characters. Second principal component (PC2) with Eigen-value of 1.358 was contributed mainly by fruit shape (0.405), which contributed to 22.60 per cent of the total variation. The third principal component (PC3) accounted for 19.00 per cent of the total variation, with high contributions from colour of tender fruits harvested at 3 days after anthesis (0.701) and presence or absence of seed cavity (0.537). Loading of different variables based on the first two principal components (Fig. 6) indicated that fruit skin colour and texture contributed a greater proportion of the total variability. Similar results of fruit characters contributing significantly to the total divergence have also been reported by Manohar and Murthy (2011); Kumar *et al*. (2014) and Pal *et al*. (2018).

Conclusion

Attractive fruit skin colour like light green/green, uniformly long cylindrical fruits with crispy tender flesh, smooth surface without prominent spines, prickles and crook-neck are the primary objectives of breeding for the quality characters in cucumber (Kumar *et al*., 2017). As majority of the accessions studied were landraces, high variability was observed among them for most of the characters. Fruit skin colour, fruit shape, flesh colour, fruit skin texture and colour of the tender fruits at 3 days after anthesis, were a few of the most variable characters observed among the accessions studied. Sixteen accessions possessed elliptical elongate shape with light green fruit skin colour, whereas, 10 accessions possessed elliptical elongate fruits with green skin colour. IC613475 which possessed elliptical elongate shape

Table 4. Mean ranks recorded for organoleptic qualities in 53 cucumber landraces

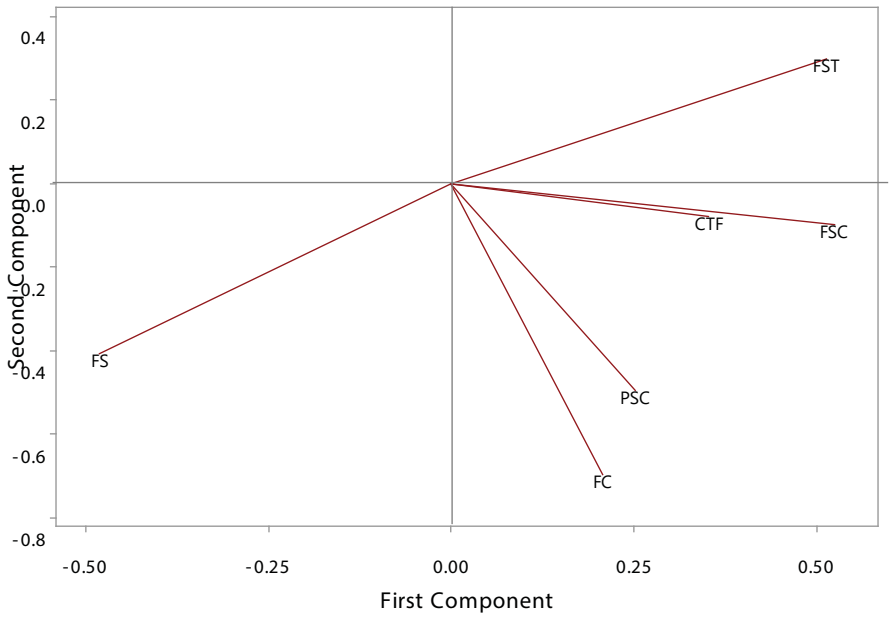
Accession No.	Bitterness	Crispness	Flavour	COS	Accession No.	Bitterness	Crispness	Flavour	COS
IC613457	26.03	27.54	23.68	77.25	IC613477	32.20	37.11	24.71	94.02
IC595504	30.07	39.21	25.43	94.71	IC613478	31.77	16.96	32.64	81.37
IC613458	30.93	19.50	25.04	75.47	IC613479	32.33	31.43	26.71	90.47
IC595505	29.67	25.00	24.43	79.10	IC613480	32.87	36.14	31.02	100.03
IC613459	3.97	18.07	18.93	40.97	IC613481	33.53	36.32	31.80	101.65
IC612081	25.10	14.86	27.50	67.46	IC613482	25.13	22.61	29.57	77.31
IC613461	25.00	13.32	31.79	70.11	IC613483	30.43	24.36	25.54	80.33
IC613462	30.27	25.68	26.43	82.38	IC613484	34.10	32.18	30.75	97.03
IC612082	28.50	18.61	25.93	73.04	IC613485	31.50	30.89	27.64	90.03
IC613465	26.97	8.32	30.29	65.58	IC613474	29.70	36.57	24.50	90.77
IC613466	27.97	12.61	32.32	72.90	IC595518	32.53	27.61	26.07	86.21
IC613467	30.57	26.07	25.00	81.64	IC618084A	28.17	42.18	28.93	99.28
IC613488	28.83	30.07	30.00	88.90	IC331445	33.07	34.46	26.29	93.82
IC595508A	28.20	29.04	26.89	84.13	IC331627	2.90	23.61	18.43	44.94
IC613460	29.87	15.14	25.57	70.58	IC277048	2.73	24.07	20.43	47.23
IC595510	32.70	32.96	24.07	89.73	IC331619	9.43	34.71	25.29	69.43
IC618083	29.47	23.14	28.86	81.47	IC541367	35.13	27.61	30.71	93.45
IC595512	33.53	27.50	33.96	94.99	IC541391	27.37	16.50	28.79	72.66
IC595514	15.40	8.57	34.64	58.61	IC469517	31.83	27.43	34.68	93.94
IC595515	29.90	26.07	25.75	81.72	IC539818	28.20	23.25	26.50	77.95
IC595517	30.60	33.68	22.11	86.39	IC277030	29.97	21.32	28.11	79.40
IC613471	29.90	41.21	23.64	94.75	IC613470	31.40	36.75	26.21	94.36
IC613472	27.47	22.93	24.18	74.58	IC202058A	3.53	16.79	21.79	42.11
IC613473	22.77	26.86	30.18	79.81	AAUC-2	27.43	38.14	30.46	96.03
SKYAC-239	29.70	24.71	23.86	78.27	Poinsette	29.13	30.89	29.71	89.73
IC613475	27.23	31.04	21.96	80.23	Swarna Agethi	15.07	39.57	25.32	79.96
IC613476	28.93	39.82	25.96	94.71	Minimum	2.73	8.32	18.43	40.97
					Maximum	35.13	42.18	34.68	101.65
COS: Cumulative organoleptic score Kendall's coefficient						**0.41**	**0.33**	**0.07**	

Table 5. Eigen value and eigen vectors of the first five principal components

Variables	PC1	PC2	PC3	PC4	PC5
Eigenvalue	2.084	1.358	1.140	0.566	0.497
Per cent variance	0.347	0.226	0.190	0.094	0.083
Cumulative variance (%)	0.347	0.574	0.764	0.858	0.941
Fruit skin colour	0.524	0.098	0.286	-0.502	0.546
Fruit shape	-0.480	0.405	0.254	-0.129	0.441
Flesh colour	0.207	-0.697	0.003	-0.625	0.112
Fruit skin texture	0.514	-0.300	0.270	-0.349	0.333
Presence of seed cavity	0.253	-0.495	0.537	0.468	0.343
Colour of tender fruits at 3 DAA	0.352	-0.079	0.701	-0.030	0.517

with cream coloured skin may be a promising genotype for breeders to develop white skinned varieties. Eight genotypes possessed good storability with weight loss of less than 10 g and storage days of 4-6 days. IC613481 and IC613480, collections from West Bengal ranked superior with respect to organoleptic scoring and other traits. IC613481 produced fruits with an average single fruit weight of 238 g, whereas it was 159 g in IC613480. The shelf life of fruits was more than 4 days with an average weight loss of 13.71g and 8.81g in IC613480 and IC613481, respectively. Both the accessions possessed an FL/FD ratio of 3.42 indicating the elliptical elongated fruit shape. Significantly high field tolerance to downy mildew disease was observed among the accessions. Furthermore, there is an urgent need to strengthen the orange fleshed cucumber germplasm, genome mapping for their utilization in breeding programme to develop carotenoid rich cucumber, which might play a significant role in contributing towards nutritional security (Ranjan *et al*, 2019)

Characterisation also allows identification of the most similar accessions that can be discarded by the breeders, this being the first step to the rationalization of the collection (Valcarcel *et al.*, 2018). Studies on genetic diversity analysis using the qualitative traits and their correlation with SSR markers have the



FSC-Fruit skin colour; FS-Fruit shape; FFC-Fruit flesh colour; FST-Fruit skin texture; PSC-Presence of seed cavity; CTF-Colour of tender fruits at 3 DAA

Fig. 6. Loading of different characters based on the first two principal components

potential to identify redundancy among the germplasm accessions (Yang *et al.*, 2015). Hence, a detailed study on inheritance of qualitative characters may be undertaken to identify unique morphological markers specific to various accessions. Further, molecular marker analysis to determine the genomic location via fine mapping, candidate gene analysis and dissection of closest flanking markers for marker assisted selection may help the breeders to investigate the genetic control of these traits. The genes from wild relatives namely *C. sativus* var. *hardwickii*, *C. setosus*, *C. hystrix* and *C. muriculatus* can also be exploited for cucumber improvement. Apart from the accessions included in this study, many high quality landraces still exist in the country, especially in North Eastern belt, which have been cultivated by farmers for centuries both for consumption and to meet the local market demand.

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