



## EVALUATION OF STRAWBERRY (*Fragaria* × *ananassa* Duch.) CULTIVARS FOR FRUIT QUALITY AND BIOCHEMICAL CHARACTERS UNDER NORTH-WESTERN PLAINS OF INDIA

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**ABSTRACT :** The present investigation was conducted on "Evaluation of strawberry (*Fragaria* × *anasassa* Duch.) cultivars under sub tropical conditions of Punjab". The objectives of this study was to evaluate ten strawberry cultivars viz. 'Chandler', 'Camarosa', 'Sweet Charlie', 'Antana', 'Ofra', 'Gorella', 'Brighten', 'Catispill', 'Elaranthra' and 'Belrubi' for their yield and quality characters. The variability among different cultivars was evaluated on fruiting and biochemical characters. The significant variability was found for these characters among various cultivars. Cultivar Camarosa took maximum days to fruit set and maximum days taken upto fruit maturity was recorded in cultivar brighten. Harvesting period was early in Sweet Charlie and late in Camarosa and Chandler. The fruit length and breadth was maximum in Camarosa and Chandler. Number of flowers/plant was maximum in Antana and Catispill while the fruit weight, fruit yield/plant and fruit yield/acre was maximum in Chandler and Camarosa. Maximum TSS and TSS/acid ratio was recorded in Sweet Charlie, highest acidity was found in Gorella and maximum total sugars in Camarosa. Highest vitamin C and anthocyanin was recorded in Ofra and Sweet Charlie, respectively.

**Keywords :** Strawberry, genotypes, fruit quality, biochemical traits.

Strawberry (*Fragaria* × *ananassa* Duch.) is an herbaceous plant belongs to family Rosaceae. It is an aggregate fruit and octaploid in nature having basic chromosome number  $2n = 8x = 56$ . Strawberry is a unique plant species with highly valuable fruits rich in vitamin C, minerals, anthocyanins, flavonoids, fibre and sugars (Perez *et al.*, 12). Strawberry is one of the delicious and nutritious fruit among the soft fruits. Strawberry fruits are reported to possess astringent, diuretic and antiseptic properties (Karakas *et al.*, 10). It is one of the few fruit crops which give very quick and high returns per unit area as crop is ready to harvest within five months (Sharma and Sharma, 17). Being a quick growing it is suitable for kitchen garden. The strawberry fruit have 98 per cent edible portion.

Strawberry is eaten as fresh and highly used in processing industry for making various products. Fruit colour, texture, odour and the balance between sweetness and sourness have been identified as important determinants of overall quality of strawberry fruit (Shamaila *et al.*, 14).

Due to the availability of large germplasm in strawberry there is large variation in the adaptability to different agro-climatic condition among different

genotypes. Among all characters fruit character have always remained of prime importance and are much influenced by environmental factors. Since strawberry is a crop of temperate regions of the world, its cultivation has been extended to subtropical regions like Maharashtra, Punjab, and Haryana. Variations in strawberry fruit quality are mainly related to genotypes and this confirms the importance of cultivars with improved and stable fruit quality (Diamanti *et al.*, 7).

Badiyala and Bhutani (3) and Kumar *et al.* (11) reported the potentiality of growing strawberry in the irrigated subtropical regions of North India and they also reported the high yield realizations when planting was carried out during the last week of September in those tracts. Several genotypes are available in strawberry but the photo/thermo sensitive nature of this crop warrants the testing of these genotypes for its adaptability in new areas before recommending for commercial cultivation. Varietal performance under diverse agro climatic condition also plays an important role to quantify the best suited cultivars for the particular agro-climatic condition to reap maximum yield with desirable quality attributes. Therefore, the present study was conducted with the objectives to evaluate the strawberry cultivars for fruit quality and biochemical characters under agro-climatic conditions of North-Western plain of India.

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## MATERIALS AND METHODS

The experiment was conducted in sub-tropical agro-climate of Ludhiana during 2014-16 situated at Latitude 30° 4' N Longitude 75° 5' E at 256 m AMSL. The uniform strawberry plants of 10 cultivars Chandler, Camarosa, Sweet Charlie, Antana, Gorella, Ofra, Catispill, Elaranthra, Brighten, Belrubi were procured from Dr YS Parmar University for Horticulture & Forestry, Nauni (Solani) Himachal Pradesh. The plants of ten strawberry cultivars were transplanted during 2<sup>nd</sup> fortnight of October on raised beds of size 5m × 1.2m and fertigation was applied at significant intervals. The plants were sprayed uniformly with fungicides for different diseases. During December-January months plants were protected from frost by covering them with plastic sheets of 100 micron. This experiment was replicated four times in Randomized Block Design (RBD). Total number of plants per replication was 30 and spaced at 30 × 30 cm.

The fruit samples were collected at different intervals *i.e.* 4, 8, 12, 16 and 20 days after fruit set for fruit development studies from different strawberry cultivars to optimize physiological maturity. Fruit length and breadth was measured with the help of digital vernier's caliper and mean was calculated. The time taken by the flower to set the fruit after the initiation of flowering was considered as time taken to fruit set. The days taken by the fruit to maturity after the fruit set were considered as time taken to maturity. Harvesting period was recorded from the first picking to the last picking of fruits in a cultivar. The weight of the representative fruits of each cultivar both marketable and undersized fruits from each plant was recorded and average weight per berry was worked out. Number of fruits per plant both marketable (average size > 12 g) and

undersized (< 12 g) were counted at the time of maturity and total number of fruits were also recorded. The fruits which were undersized are considered as non-marketable.

The yield per plot was calculated by multiplying the mean weight with average number of fruits harvested per plant.

Total soluble solids were recorded from the juice obtained from randomly selected berries from all the cultivars in each replication with the help of Erma hand Refractometer of 0-32 °Brix range. Acidity and sugar contents were calculated by the method given by A O C (1). Total soluble solid acid ratio and sugar/acid ratio was estimated by dividing total soluble solids and sugars by titratable acidity. The vitamin C content was calculated by the method given by AOAC (1). The Anthocyanin content was calculated

## RESULTS AND DISCUSSION

Results pertaining to fruiting characters (Table 1) showed significant variations in terms of fruiting characters. Maximum number of days taken for fruit set *i.e.* 3 days were recorded in 'Camarosa' and 'Gorella'; however, 'Sweet Charlie' and 'Chandler' took 2.8 days and all were at par with each other. The strawberry cultivars 'Brighten' and 'Belrubi' had taken maximum time (20.3 days) for fruit development in comparison to rest of genotypes. However, cultivar 'Camarosa', 'Ofra', and 'Gorella' attained physiological maturity within 19.3 days and 'Brighten' and 'Belrubi' in 20.3 days. The time taken to fruit maturity by other cultivars varied from 18.0 days in 'Sweet Charlie' to 16.3 days in 'Antana'. The results of present study were in contradictory with the results obtained by Dennis *et al.* (5) who found strawberry fruits take 30-40 days to attain fully ripe

**Table 1 : Performance of different strawberry cultivars for fruit characters under Ludhiana conditions.**

Cultivars	Time for fruit set	Fruit maturity (Days)	Harvesting Period	Fruit length (cm)	Fruit breadth (cm)
Chandler	2.8	17.8	8 Feb-6 April	3.70	3.26
Camarosa	3.0	19.3	6 Feb-5 April	3.96	3.34
Sweet Charlie	2.8	18.0	25 Jan-18 March	2.73	2.32
Antana	2.0	16.3	2 Feb-17 March	2.22	1.91
Ofra	2.3	19.3	6 Feb-23 March	3.01	2.86
Gorella	3.0	19.3	2 Feb-20 March	2.70	2.44
Brighten	2.5	20.4	5 Feb-29 March	2.57	2.22
Catispill	2.3	16.0	1 Feb-17 March	2.38	2.17
Elaranthra	2.0	17.8	4 Feb-23 March	2.59	2.30
Belrubi	2.0	20.3	8 Feb-31 March	2.44	2.04
CD (P=0.05)	0.45	1.59		0.67	0.53

**Table 2 : Periodical increase in fruit diameter of various strawberry cultivars.**

	Fruit length (cm)					Fruit diameter (cm)				
	Days					Days				
Cultivars	4	8	12	16	20	4	8	12	16	20
Chandler	1.54	2.25	3.18	3.42	3.70	1.47	2.08	3.02	3.13	3.26
Camarosa	1.80	2.46	3.12	3.36	3.96	1.49	2.3	3.03	3.28	3.34
Sweetcharlie	1.21	1.6	2.12	2.44	2.73	1.09	1.29	1.88	2.03	2.32
Antana	1.04	1.39	2.12	2.22	0	1.00	1.24	1.42	1.91	0
Ofra	1.12	1.65	2.12	2.64	3.01	1.08	1.54	1.76	2.38	2.86
Gorella	1.00	2.05	2.25	2.49	2.70	1.02	1.34	2.12	2.29	2.44
Brighten	1.07	1.48	1.93	2.38	2.57	1.14	1.54	1.77	2.02	2.22
Catispill	1.15	1.64	1.93	2.25	2.38	1.08	1.47	1.78	2.02	2.17
Elarantha	1.12	1.57	1.87	2.26	2.59	1.23	1.68	2.05	2.15	2.30
Belrubi	0.91	1.49	2.00	2.34	2.44	0.94	1.57	1.84	1.99	2.04
<b>Mean</b>	<b>1.20</b>	<b>1.76</b>	<b>2.26</b>	<b>2.58</b>	<b>2.61</b>	<b>1.15</b>	<b>1.61</b>	<b>2.07</b>	<b>2.32</b>	<b>2.30</b>
CD (P=0.05) Cultivars	0.17					0.88				
Days	0.12					0.62				
Cultivars × Days	0.39					0.19				

stage after flowering while in present studies the majority of cultivars took 15-20 days to reach the maturity after fruit set. Gupta (8) evaluated strawberry cultivars under mid hills of H.P. and reported that various cultivars had taken comparatively more number of days to attain physiological maturity.

The harvesting in cultivar ‘Sweet Charlie’ was started on 25<sup>th</sup> January and almost completed up to 18 March and this variety had been classified into early fruit maturity group among all the cultivars under studies. ‘Chandler’ strawberry was observed late season cultivar and fruits were available in between 8<sup>th</sup> February to 6<sup>th</sup> April under Ludhiana conditions of north India. The strawberry cultivars viz. ‘Antana’, ‘Sweet Charlie’, ‘Gorella’, ‘Catispill’, ‘Ofra’ and ‘Elarantha’: were grouped ‘early’ season, ‘Belrubi’ as ‘mid’ season and ‘Camarosa’, ‘Chandler’ and ‘Brighten’ as ‘late’ season varieties. Cultivar ‘Camarosa’ had significantly maximum fruit length (3.96 cm) followed by ‘Chandler’ (3.70 cm) and it was least (2.22 cm) in ‘Antana’ cultivar. Fruit breadth was found to be maximum in cultivar ‘Camarosa’ (3.34 cm) and ‘Chandler’ (3.26 cm) and it ranged from 2.86 cm in ‘Ofra’ to 1.91 cm in ‘Antana’. Cultivars ‘Camarosa’ and ‘Chandler’ showed the maximum fruit length and breadth respectively. These results are in agreement with the results of Gupta (8) who reported higher length and breadth in ‘Chandler’ fruits. The results are also in conformity with Recuperero *et al.* (13) who also reported the larger fruits in ‘Chandler’. Sharma *et al.* (16) also

reported ‘Chandler’ cultivar was superior in terms of fruit size than the rest of cultivars under studies. Strawberry cultivars differed significantly with regard to fruit length, breadth, berry weight and yield (Sharma *et al.*, 16).

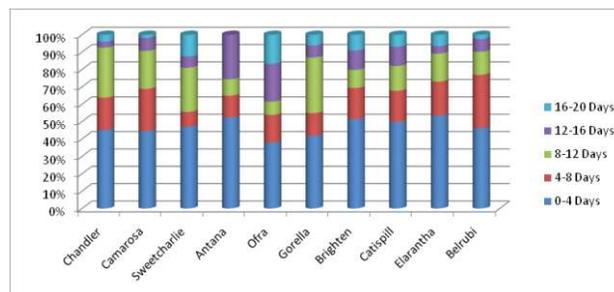


Fig 1 : Increment (%) in fruit size during different fruit development stages in different strawberry cultivars.

The perusal of data reveals significant differences among different cultivars in terms of increase in fruit size at different days interval (4, 8, 12, 16 and 20) as shown in Table 2. The different genotypes had shown significantly higher increase in fruit length up to 1.20 cm during initial fruit development periods i.e. 1 to 4 days after fruit set (DAFS). The increase in fruit length was comparatively lesser (2.58-2.61 cm) during fruit growth period between 16 to 20 DAFS similarly; however, maximum rate of growth in term of fruit diameter to the tune of 1.15 cm was recorded between 0 to 4 DAFS. Dhaliwal and Singh (6) also determined sufficient variation in fruit size among different

strawberry cultivars. The results obtained in the present study are in the conformity with Recupero *et al* (13) who reported larger fruit size in 'Chandler' and 'Pajaro'.

Significantly heavier average marketable fruits of 18.4 g were recorded in 'Camarosa' followed by 'Chandler' (17.9 g) and both the cultivars were at par with each other (Table 3). Fruit weight of rest of the cultivars ranged varies from 'Sweet Charlie' (16.0 g) and the least 12.0 g in 'Antana'. The marketable fruits of 'Camarosa' and 'Chandler' were significantly heavier than other cultivars. The marketable fruit weight in 'Elarantira' (14.4), 'Brighten' (13.6), 'Gorella' (13.6), 'Belrubi' (12.9) and 'Catispill' (12.7) were statistically at par with each other. The highest fruit weight among undersized fruits were recorded in 'Gorella' 9.0 g followed by 'Ofra' (8.1 g) and 'Camarosa' (8.1 g) and all these were statistically at par with each other and the least 6.3 g in 'Belrubi', however, 'Antana' (6.3 g) was at par with 'Belrubi' cultivar. These results are also in agreement with the findings of Gupta (8) who found higher fruit weight in 'Chandler' under Nauni conditions of Himachal Pradesh.

Maximum marketable fruits per plant were recorded in 'Chandler' (13.8) while 'Camarosa' (12.3) was statistically at par with 'Chandler' (Table 3). 'Sweet Charlie' (11.3) and 'Brighten' (10.3) was at par with 'Camarosa' but differed significantly from 'Chandler'. Cultivar 'Antana' (1.0) had the significantly lesser marketable fruits than all other cultivars under study. Cultivar 'Catispill' had 27.0 numbers of total fruits per plant which were significantly higher than the rest of strawberry cultivars. Total number of fruits in rest of the cultivars varied from 21.0 in 'Antana' to 13.0 in 'Gorella' which was significantly least among all the cultivars. Cultivar 'Sweet Charlie' and 'Chandler' had produced 20.9 and 18.5 fruits/plant, respectively. Results obtain under the present study were in contradiction with the results obtained by Gupta (8) under Nauni conditions as he reported less number of total fruits per plant in 'Chandler', 'Belrubi' and 'Brighten'.

The highest marketable yield of 246.1 g per plant was recorded in cultivar 'Chandler' which was significantly higher than 'Camarosa' which yields 227.4 g of fruits per plant (Table 3). Minimum marketable yield per plant of 12.0 g was recorded in 'Antana'. The highest cumulative yield per plant of 283.3 g was recorded in cultivar 'Chandler' which was significantly higher than 'Camarosa' (262.4 g) and 'Sweet Charlie' (251.5). The least total yield per plant was recorded in cultivar 'Belrubi' which yields 146.3 g per plant. The total yield was found highest in cultivar 'Chandler' 9.79

MT/acre which was significantly higher than all other cultivars undertaken study. 'Camarosa' and 'Sweet Charlie' yielded 9.07 MT/acre and 8.70 MT/acre. The least total marketable yield was recorded in 'Gorella' 5.36 MT/acre. The present study found that 'Chandler' had the maximum fruit yield per plant as well as per acre which are in the agreement with the results obtained by Recupero *et al.* (13) who had also reported the maximum yield of 'Chandler' under Italy and Paris conditions, respectively. Gupta (8) also reported 'Chandler' as high yielder under Nauni, Solan conditions. The variation in the yielding potential may be ascribed to the fact that strawberry yields are markedly influenced by environmental parameters like photoperiods, temperature and light intensity (Avidov, 2).

The data in Table 4 represent total soluble solids (TSS) content recorded in different strawberry cultivars and significant differences were observed among the cultivars. TSS content ranged from 9.5 °B in 'Sweet Charlie' to 6.9 °B in 'Gorella' and 'Catispill'. 'Chandler' (8.7), 'Ofra' (8.5) and 'Belrubi' (8.5) were statistically at par with each other. The results obtained in the present study have been confirmed the findings of Veazie (18) who also reported that soluble solids in ripe berries varies from 4.0 to 11.0°B. The possible differences may be due to the fact that varieties grown under sunny days and cool nights have better TSS and acid content than those grown under cloudy, humid and warm nights (Avidov, 2).

Cultivar 'Gorella' had the significantly higher acidity i.e. 1.12 per cent while 'Belrubi' 1.04 per cent which was at par with 'Gorella' (Table 4). The least acidity was recorded in 'Sweet Charlie' (0.76 %). All the other cultivars under evaluation were at par with each other. The results obtained in the present study have been confirmed the findings of Veazie (18) who also reported that the content of acidity in ripe berries varies from 0.45 to 1.81 per cent. The possible explanations for such differences may be due to the fact that varieties grown under sunny days and cool nights have better TSS and acid content than those grown under cloudy, humid and warm nights (Avidov, 2).

It is pertinent to mention that significant variation in juice TSS/acid ratio in different cultivars was noted (Table 4). Cultivar 'Sweet Charlie' had the maximum (12.5) TSS/acid ratio which were significantly higher than all other cultivars. Cultivar "Chandler" and 'Camarosa' had the TSS/acid ratio of 10.3 and 11.1, respectively. The least TSS/acid ratio was recorded in 'Gorella' 6.2. Gupta (8) also observed significant

**Table 3 : Performance of strawberry cultivars for their yield related parameters.**

Cultivars	Number of fruits/plant		Fruit weight (g)		Fruit yield/plant (g)		Fruit yield/acre (MT)	
	Marketable Fruits	Total number of fruits	Marketable fruits	Undersized fruits	Marketable yield	Total yield	Marketable yield	Total yield
Chandler	13.8	18.5	17.9	8.0	246.1	283.3	8.52	9.79
Camarosa	12.3	16.7	18.4	8.1	227.4	262.4	7.82	9.07
Sweet Charlie	11.3	20.9	16.0	7.5	179.4	251.5	6.21	8.70
Antana	1.0	21.0	12.0	6.3	12.0	161.9	0.42	5.60
Ofra	9.3	16.0	14.9	8.1	137.7	188.1	4.77	6.50
Gorella	8.5	13.0	13.6	9.0	115.3	155.0	3.99	5.36
Brighten	10.3	16.7	13.6	7.4	139.6	186.3	4.82	6.43
Catispill	7.0	27.0	12.7	6.9	88.8	227.2	3.06	7.86
Elaranthra	9.5	16.3	14.4	7.4	136.3	188.8	4.71	6.52
Belrubi	8.5	15.0	12.9	6.3	109.4	146.3	3.79	5.05
CD (P=0.05)	1.29	3.15	2.4	1.1	2.76	4.03	0.41	0.14

differences in various strawberry cultivars with regard to TSS/acid ratio.

The strawberry cultivars under evaluation had shown significant differences in terms of reducing and non-reducing sugars (Table 4) and it ranged from 5.88 to 4.45 per cent. Cultivars 'Camarosa' (5.88%) showed significant higher levels for reducing sugars in comparison to other cultivars while 'Chandler' had 5.44% reducing sugars. The lowest reducing sugars of 4.45 percent were registered in 'Brighten'. 'Antana' cultivar recorded significantly higher percentage of non-reducing sugars of 1.10 percent (Table 13). The lowest non-reducing sugar was recorded in 'Belrubi' (0.73%) except 'Gorella' (1.05) and 'Elaranthra' (0.87) all other cultivars were at par with each other in respect to non-reducing sugar.

The mean transformed data on total sugars revealed significant differences among cultivars (Table 4) and values of total sugars varied from 6.64 to 5.28 per cent. The highest total sugars were recorded in 'Camarosa' (6.64%) followed by 'Chandler' (6.22%). The levels of sugar contents of strawberry fruits observed in present studies are in agreement with the investigations of Dhaliwal and Singh (6) who reported 4.1 to 10.5 percent sugars in strawberry fruits. The reasons for deviation in fruit sugar may be described due to the differences in growing conditions and climatic variation (Sharma and Thakur, 15).

Significant differences were observed among the various cultivars with respect to Vitamin C content. The value of vitamin C ranged from 88.1 mg/100 g to 41.00 mg/ 100 g in different strawberry cultivars under

**Table 4 : Performance of strawberry cultivars for biochemical characters.**

Cultivars	TSS (°B)	Acidity	TSS/acid ratio	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)	Vitamin C (mg/100g)	Anthocyanin (mg/100g juice)
Chandler	8.7	0.85	10.3	6.22	5.44	0.78	61.2	56.3
Camarosa	9.2	0.83	11.1	6.64	5.88	0.76	57.1	63.0
Sweet Charlie	9.5	0.76	12.5	5.50	4.60	0.90	85.6	66.0
Antana	7.6	0.85	9.0	5.65	4.55	1.10	42.9	43.3
Ofra	8.5	0.97	8.8	6.42	5.52	0.90	88.1	48.3
Gorella	6.9	1.12	6.2	5.62	4.57	1.05	47.5	35.5
Brighten	7.8	0.98	8.0	5.28	4.45	0.83	60.5	32.8
Catispill	6.9	0.78	8.8	6.34	5.25	1.09	66.3	44.8
Elaranthra	7.0	0.98	7.1	6.35	5.48	0.87	54.7	54.0
Belrubi	8.5	1.04	8.2	6.44	5.71	0.73	41.0	61.5
CD (P=0.05)	0.34	0.25	0.44	0.47	0.26	0.34	2.25	3.28

evaluation (Table 4). The maximum value of vitamin C content was recorded in cultivar 'Ofra' (88.1 mg/100g) which was significantly higher than all other cultivars. Cultivar 'chandler' and 'Camarosa' had the vitamin C content of 61.2 mg/100g and 57.1 mg/100g respectively. The least value was found in 'Belrubi' (41.00 mg/100g). However, rest of the cultivars also showed significant differences among them. In the present study cultivar 'Ofra' and 'Sweet Charlie' had the highest vitamin C content among all the cultivars under taken evaluation. The results were fully agreement with the results found by Jami *et al.* (9) who also reported higher vitamin C content in 'Ofra' and 'Sweet Charlie', respectively.

The data shown in Table 4 revealed significant variation in respect to anthocyanin content present in the fruits. The highest amount of anthocyanin content was found in 'Sweet Charlie' (66.0 mg/100 g) while 'Camarosa' (63.0 mg/100 g) was at par with 'Sweet Charlie'. Cultivar 'Chandler' had 56.3 mg/100g of anthocyanin in fruit pulp. The lowest value of anthocyanin was recorded in 'Brighten' (32.8 mg/ 100 g). Significant variation was also observed among other cultivars undertaken study. In the present study 'Camarosa' had the higher value of Anthocyanin i.e. 63.0. Regarding berry fruits, recent researches confirm the role of genotype as the main source of variation in anthocyanin and sugar content (Crespo *et al.*, 4).

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