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Influence of different growth conditions on earliness, yield and quality of strawberry production in South Kashmir

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ABSTRACT

Strawberry is one of the important fruit crop of temperate region, hence its cultivation is gaining popularity in Kashmir valley. Yield and fruit quality of strawberry is influenced by a number of factors like growing environment, soil condition and cultivars. Growth and productivity of eight strawberry cultivars were studied during 2009-10 and 2010-11 growing seasons under open and polyhouse conditions at Krishi Vigyan Kendra, Pulwama of South Kashmir. The study was conducted to identify the suitable environment for earliness and high production of good quality fruits. Under polyhouse conditions, first flower was produced by Tioga after 107 days of planting, whereas Catskill produced after 142 days in open conditions. Chandler produced flower for long duration (46.56 days) along with maximum number of flowers, *i.e.* 24.15 and 28.64 under both growing conditions, while in open conditions Confutura flowered for maximum number of days, *i.e.* 62.53 days. Maximum yield was obtained in open conditions from Chandler (2.41 kg/ plot) closely followed by Tioga (2.38 kg/ plot), while under polyhouse conditions Tioga (1.63 kg/ plot) yielded maximum followed by Chandler (1.62 kg/ plot). Strawberry fruits were of similar quality regardless of the growing condition, however, earliness in fruiting was evident under protected condition, which also provided protection from low temperatures and in turn, making its cultivation more remunerative. Yield was more under open conditions compared to protected conditions.

Key words: Growth conditions, earliness, yield, quality, strawberry.

INTRODUCTION

Strawberry (*Fragaria* × *annanasa* Dutch.) has been grown commercially in various parts of the world for many years but in India it was only introduced in the early 1960's (Sharma and Sharma, 14) and has now acclimatized well in different parts (Sharma and Yamdagni, 13). The added advantage with strawberry is that it gives early and very high returns per unit area compared to other fruit crops because the crop is ready for harvest within six months from planting. Although the strawberry cultivation was previously concentrated in the temperate region, with advent of day neutral cultivars, it is now profitably grown in the subtropical and tropical regions as well. This fruit crop can be grown in subtropical to temperate climates, hence its cultivation is gaining popularity in Kashmir valley considering its suitability as an intercrop in the initial years of establishment of apple and pear orchards so as to utilize the space and light and maximize the returns per unit area (Ahmad, 1). The standard planting time in the valley ranges from late October to the first fortnight of November, and harvesting from 15 March to late April in controlled conditions and from the second fortnight of April to late May in open conditions. Climatic conditions under various production systems during the growing season may affect fruit quality. Soluble solids concentration, acidity and colour of strawberry fruit have been reported to be affected by environmental factors (Sacks and Shaw, 11; Vlachonasios *et al.*, 17), as well as harvest date (Shaw, 15). In Kashmir valley, cultivation is generally carried out under open field conditions to take the advantage of the local climatic conditions, but due to the long duration of winters the availability of fruit is very late. However, growing strawberries under protected conditions decreases the maturation period, which is dependent on climate and soil conditions. Under open conditions, the bulk of productions usually occur in May-June, when other local fruits especially the stone fruits are available and the average fruit price in the market is quite low. Thus, to maintain profitability of strawberry production in Kashmir valley, the present study was conducted both under protected and open conditions.

MATERIALS AND METHODS

The experiment was laid out under polyhouse and open conditions during 2009-10 and 2010-11 at Krishi Vigyan Kendra, Pulwama, Jammu and Kashmir. The KVK is located at 33° North and 74° East at an altitude of 1601 m amsl. The mean annual rainfall

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ranges from 500 to 850 mm. The minimum and maximum temperatures of the station during summers range between 10 and 30°C and -4 and 10°C during winter under open conditions. A polyhouse with steel pipe framework clad with twin layer UV stabilized 200 µm plastic sheet was used to create a modified environment. The polyhouse was additionally fitted with a high pressure fan on East-West side. The soil of the location is silty clay loam neutral in reaction (pH 7.07) having organic C 10.02 g/ kg, available N 248.6 kg/ha, available P 14.7 kg/ ha and available K 250.3 kg/ha. The experimental materials were comprised of eight commercial cultivars, namely, Catskill, Chandler, Confutura, Gorella, Pajaro, Selva, Tioga and Fern collected from SKUAST-K and the Department of Horticulture, Ramban, Jammu and Kashmir. With three replications, the experiment was laid out in completely randomized block design (CRBD) in polyhouse and randomized block design (RBD) under open conditions. The spacing between the runners was 30 × 30 cm in 1 × 1 m^2 raised beds of 15 cm height with 55 cm spacing between the beds. Uniform runners were planted in the first week of November 2009 in three rows on each bed accommodating nine runners. For the second year crop, the emerged runners were removed in the last week of October 2010 in order to maintain the proper spacing for the next year's crop. Usual irrigations, manures and fertilizers, weeding and hoeing were applied uniformly to the experimental plots during the study years under both conditions.

Data were recorded for different growth, flowering and fruiting characters for two years. Plant spread (cm) and length of the runners (cm) was measured with the help of a measuring tape. Number of runners per plant, number of flowers per plant and number of berries per plant were counted from five randomly selected plants. Days to first flower was recorded from the date of planting of runners to initiation of first flower. Flowering duration was counted by subtracting the days to initiation of first flower from the days to last flowering. Percentage of berry set was calculated by dividing the number of berries by the number of flowers. Yield per plant (g) was calculated by weighing whole fruits harvested from a single plant. Ten fruits were randomly selected for all the physio-chemical characters. Berry weight was determined with the help of a weighing scale; berry length and width were determined using a Vernier calipers. TSS, acidity and TSS/acid ratio were estimated using standard procedures. Total and reducing sugars were determined by Shaffer Somogy's, micro-method (Ranganna, 10). Data on temperature and humidity were recorded with a portable thermohygrometer.

The pooled data of two years were statistically analyzed (Panse and Sukhatme, 8). The mean of attributes were compared by paired 't' test and the least significant difference was calculated at 5 per cent level.

RESULTS AND DISCUSSION

Data in Table 1 indicate a significant influence of growth conditions on various growth and flowering characters of different varieties studied. Maximum plant spread (24.40 cm), number of runners per plant (8.42) and runner length (77.02 cm) was observed under polyhouse conditions, however duration of flowering (57.46 days) and number of flowers per plant (24.44 days) recorded maximum values under open conditions because of fact that there is continuous fluctuation of temperature during the growth stage, which has direct effect on the duration of flowering. Under polyhouse conditions, first flower was produce after 114 days of planting of runners, whereas, under open conditions first flower was produce after 150.37 days, which is directly correlated with the temperature.

Table 1. Growth and flowering characters of strawberry cultivars under protected and open conditions.

Cultivar	Plant spread (cm)		No. of runners/ plant		Runners length (cm)		Days taken to first flower emergence		Duration of flowering		No. of flowers/ plant	
	Polyhouse	Open	Polyhouse	Open	Polyhouse	Open	Polyhouse	Open	Polyhouse	Open	Polyhouse	Open
Catskill	26.95	24.57	9.12	7.56	83.23	75.27	116	142	40.75	58.38	22.68	27.78
Chandler	28.34	25.56	10.45	8.08	84.60	67.42	111	147	46.56	60.27	24.15	28.64
Confutura	25.81	22.25	8.32	6.14	91.55	55.35	109	145	43.58	62.53	19.39	23.42
Gorella	24.44	20.41	7.76	6.23	77.08	65.37	113	154	41.12	57.44	18.55	22.51
Pajaro	22.51	19.70	6.89	5.50	69.48	40.52	115	151	39.42	53.53	17.60	21.61
Selva	22.37	21.32	7.68	5.46	75.36	46.34	126	162	37.23	52.52	18.19	22.42
Tioga	23.58	22.44	10.03	6.11	72.29	59.27	107	143	45.50	60.47	23.87	26.48
Fern	21.21	19.33	7.12	5.87	62.57	55.45	120	159	38.18	54.51	17.50	22.66
Mean	24.40	21.94	8.42	6.36	77.02	58.12	114	150.37	41.54	57.46	20.24	24.44
$CD_{0.05}$	2.41	2.36	0.14	0.24	7.48	5.59	3.12	4.08	4.90	5.92	2.56	2.65

Among cultivars, Chandler (28.34 cm) recorded maximum plant spread under polyhouse, which was statistically at par with Catskill (26.95 cm), whereas, minimum plant spread was registered by Fern (21.21 cm). Similar pattern was recorded among the cultivars when observations were taken under open conditions. Maximum number of runners was produced by Chandler (10.45) cultivar was closely followed by Tioga (10.03) under controlled (polyhouse) conditions, whereas, under open field conditions Chandler (8.08) was closely followed by Catskill (7.56). Minimum number of runners was produced by Pajaro (6.89) under polyhouse and in open conditions by Selva (5.46). Earlier, Sahoo *et al*. (12) also registered similar values for plant spread and number of runners per plant. Confutura (91.55 cm) produced longest runners under controlled conditions, which were statistically at par with Chandler (84.60 cm), however, Catskill (75.27 cm) registered maximum length of runners in open conditions and was statistically higher than other cultivars. Fern (62.57 cm) under polyhouse conditions and Pajaro (40.52 cm) in open conditions produced shortest runners. After planting, first flower was produced by Tioga (107 days) under controlled conditions closely followed and statistically at par with Confutura (109 days). However, first flower in open conditions was produced by Catskill after 142 days of planting, which was statistically at par with Tioga (143 days) and Confutura (145 days). Under both conditions, Selva took maximum number of days to bear first flower. Cultivars studied by Singh *et al*. (16) took minimum of 91 days to produce first flower under North-East conditions, however, in the present study first flower was produced after 142 days of planting and this difference might be due to the sub-zero or very low temperature prevailing in Kashmir valley during the winters or growing season.

Under controlled conditions, Chandler produced maximum number of flower per plant (24.15) and for longer duration (46.56 days), which was statistically at par with Tioga (23.87) and Catskill (22.68) for number of flower per plant; Tioga (45.50 days) and Confutura (43.58 days) for duration of flowering. Confutura (62.53 days) produced flowers for long duration under open conditions, which was statistically at par with most of the cultivars except Pajaro, Selva and Fern. However, the maximum number of flowers was produced by Chandler (28.64), which was statistically at par with Catskill (27.78) and Tioga (26.48). Selva (37.23 and 52.52 days) flowered for minimum number of days under both the conditions, respectively. However, minimum number of flowers per plant was produced by Fern (17.50) under controlled conditions and by Pajaro (21.61) under open conditions.

With respect to yield and fruiting characters significant differences were recorded among the cultivars, however, all the characters registered maximum mean values in open conditions as compared to polyhouse conditions (Table 2). Chandler (18.76) recorded maximum number of berries per plant closely followed and statistically at par with Tioga (18.63) and Catskill (18.34) under controlled conditions, however, minimum number of berries was observed in Pajaro (13.45). Similar trend of cultivars performance but with higher values was noticed in open conditions. Maximum berry set under polyhouse conditions was recorded in Catskill (81.04%), which was statistically at par with Chandler (78.85%) and Tioga (78.71%), whereas in open conditions Chandler (85.21%) observed maximum berry set closely followed and statistically at par with Catskill (83.61%) and Tioga (83.55%). Minimum berry set under controlled and open conditions was registered in Gorella, *i.e.*, 75.41 and 76.67 per cent, respectively. Under polyhouse

Table 2. Yield and fruiting characters of strawberry cultivars under protected and open conditions.

Cultivar	No. of berries/ plant		Berry set (%)		Yield/plot (kg)		Berry weight (g)		Berry length (cm)		Berry breadth (cm)	
	Polyhouse	Open	Polyhouse	Open	Polyhouse	Open	Polyhouse	Open	Polyhouse	Open	Polyhouse	Open
Catskill	18.34	23.52	81.04	83.61	1.54	2.17	9.81	10.35	4.11	4.48	3.99	4.55
Chandler	18.76	24.27	78.85	85.21	1.62	2.41	9.98	11.14	4.18	4.39	4.05	4.42
Confutura	15.33	18.70	76.85	80.36	1.28	1.71	9.17	10.05	3.98	4.18	3.93	4.22
Gorella	14.18	17.42	75.41	76.67	1.22	1.56	8.14	9.85	3.88	3.81	3.64	3.72
Pajaro	13.45	17.07	76.33	79.46	1.02	1.44	7.02	9.12	3.52	3.76	3.28	3.62
Selva	14.13	17.87	77.50	78.30	1.07	1.38	6.76	8.56	3.40	3.75	3.22	3.67
Tioga	18.63	22.32	78.71	83.55	1.63	2.38	10.24	11.85	4.02	4.79	3.94	4.48
Fern	13.50	18.11	77.43	79.44	1.16	1.40	6.84	9.28	3.24	3.53	3.14	3.42
Mean	15.79	19.91	77.76	80.82	1.31	1.81	8.49	10.02	3.79	4.08	3.64	4.01
$CD_{0.05}$	1.65	2.59	2.92	3.18	0.09	0.12	0.22	0.12	0.09	0.14	0.11	0.10

conditions Tioga (1.63 kg) produced maximum yield per plot, which was statistically at par with Chandler (1.62 kg) and Catskill (1.54 kg), however, in open conditions Chandler (2.41 kg) yielded maximum fruits per plot closely followed by Tioga (2.38 kg). Under both conditions, Pajaro recorded minimum yield per plot. Highest yield (1.81 kg/plot) was recorded under open conditions as compared to polyhouse conditions (1.31 kg/plot). Higher temperature under polyhouse conditions during production season might have resulted in reduced fruit set. High temperature (> 30°C) reduces strawberry flower formation and ultimately fruit set (Heide, 5; Klamkowski and Treder, 6), however, in their study Daugovish and Larson (3) obtained marketable yield under plastic tunnel in Southern California conditions. This may be because of the fact that under open conditions in Kashmir valley strawberry runner flowers for more number of days hence there is direct correlation between long flowering season and total yield and unusually high temperatures in April-May resulted in reduced yields in tunnels.

Tioga registered maximum berry weight under controlled (10.24 g) and open (11.85 g) conditions, which was statistically higher among all the cultivars whereas, minimum berry weight was registered in the fruits of Selva, *i.e.* 6.76 and 8.56 g, respectively. Maximum berry length (4.18 cm) and berry breadth (4.05 cm) under polyhouse conditions was measured in Chandler, which was statistically at par with the cultivar Catskill (4.11 and 3.99 cm), however, in open conditions Tioga (4.79 cm) measured maximum berry length, which was statistically higher among all the cultivars and with respect to berry breadth in open conditions maximum reading was recorded for Catskill (4.55 cm) closely followed and statistically at par with Tioga (4.48 cm).

All biochemical characters varied significantly among different cultivars, however, not much variation was noticed between growth conditions except acidity and ascorbic acid. A perusal of data presented in Table 3 reveals that Confutura (9.64%) recorded the maximum TSS, which was higher among all the cultivars under controlled conditions, whereas, in open conditions Confutura (9.93%) was statistically at par with Catskill (9.86%). Minimum TSS under controlled conditions was registered by cultivar Selva (6.72%) and in open conditions by Fern (6.64%). Overall, under controlled conditions mean values for acidity was low as compared to open conditions. However, under controlled conditions minimum acidity was recorded in Catskill (0.88%), which was statistically at par with Tioga (0.89%) and Chandler (0.90%) and in open conditions, while minimum acidity was observed in Confutura (0.87%) closely followed and statistically at par with Catskill (0.91%), Tioga (0.91%) and Chandler (0.92%). TSS/acid ratio was recorded highest in Tioga (10.53) and Confutura (11.35) under polyhouse and open conditions, respectively. Fern registered maximum values for acidity and minimum values for TSS/acid ratio under both the growing conditions. Chandel and Badiyala (2) and Sahoo *et al*. (12) observed similar results with respect to most of the biochemical characters, while studying different cultivars under foothills of Himachal Pradesh and coastal region of Orissa, respectively.

Maximum values for reducing sugar under both the conditions (polyhouse and open) were recorded for Chandler, *i.e.* 6.22 and 6.45 per cent, respectively. However, minimum values under controlled conditions were observed in Selva (3.23%) and in open conditions by Fern (3.26%). Under both the conditions Chandler (8.17 and 8.28%, respectively) recorded maximum values for total sugars, which were statistically at

Table 3. Biochemical characters of strawberry cultivars under polyhouse and open conditions.

Cultivar	TSS (%)		Acidity (%)		TSS/acid ratio		Reducing sugar (%)		Total sugars (%)		Ascorbic acid (mg/100 g)	
	Polyhouse	Open	Polyhouse	Open	Polyhouse	Open	Polyhouse	Open	Polyhouse	Open	Polyhouse	Open
Catskill	9.15	9.64	0.88	0.91	10.42	10.63	5.56	5.27	8.07	8.09	46.16	50.35
Chandler	9.46	9.86	0.90	0.92	10.48	10.75	6.22	6.45	8.17	8.28	52.48	57.42
Confutura	9.64	9.93	0.97	0.87	9.98	11.35	5.38	5.85	7.51	7.91	39.50	46.50
Gorella	8.33	8.39	1.02	1.08	8.16	7.80	4.50	4.63	6.54	6.65	30.47	37.46
Pajaro	7.81	7.51	1.00	1.06	7.85	7.12	3.51	3.65	5.88	6.15	30.07	33.48
Selva	6.72	6.70	1.08	1.15	6.27	5.88	3.23	3.84	5.09	5.26	37.84	41.68
Tioga	9.32	9.56	0.89	0.91	10.53	10.58	5.81	5.88	7.99	8.19	47.12	52.59
Fern	6.83	6.64	1.12	1.19	6.13	5.61	3.46	3.26	5.21	5.30	32.58	35.51
Mean	8.40	8.52	0.98	1.01	8.72	8.71	4.70	4.85	6.80	6.97	39.52	44.37
$CD_{0.05}$	0.09	0.13	0.06	0.05	0.03	0.14	0.15	0.09	0.21	0.11	1.93	6.76

par with Catskill (8.07%) and Tioga (7.99%) under polyhouse conditions and with Tioga (8.19%) only in open conditions. Selva registered minimum values under both conditions, *i.e.* 5.09 and 5.26, respectively. Chandler scored maximum values for ascorbic acid under controlled (52.48 mg/100 g) and open (57.42 mg/100 g) conditions, which was statistically higher among all the cultivars, however, minimum values was observed in Pajaro (30.07 and 33.48 mg/100 g) under both the growing conditions. Hassan *et al*. (4) also reported similar results with respect to ascorbic acid in Chandler variety. Under polyhouse conditions as well as in open conditions not much variation was recorded for biochemical characters. Earlier Paraskevopoulou *et al.* (9) also reported that strawberries whether produced under greenhouse or field conditions were of similar quality, however, Kumar *et al.* (7) obtained good quality fruits under plastic tunnel conditions as compared to polyhouse and open conditions.

Meteorological data recorded from open and polyhouse conditions are presented in Fig. 1 and 2. Meteorological variations during growth, flowering and fruiting season, *i.e.* October to May in both the years reveal that average maximum temperature varied from 11.0 to 32.0°C under polyhouse conditions and 8.5 to 26.6°C under open conditions in both the years, while average minimum temperature varied from - 9.1 to 16.1°C under polyhouse conditions and - 4.1 to 10.9°C under open conditions in both the years. Average relative humidity varied from 39 to 70.6 per cent under polyhouse conditions and 55.5 to 83.5 per cent under open conditions in both the years.

This is a comprehensive study comparing strawberry yield and vegetative growth responses to the climatic conditions in protected and open

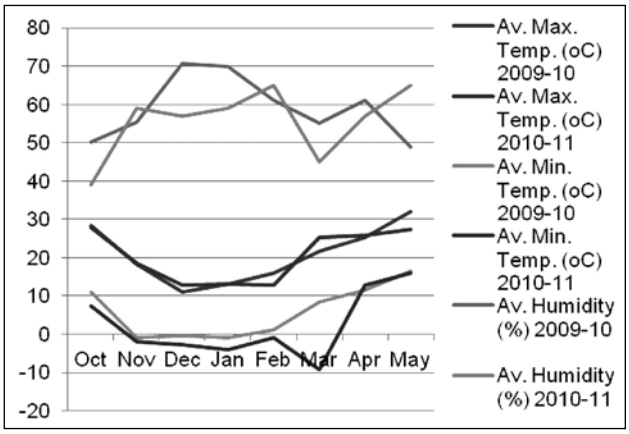

Fig. 1. Month-wise average maximum, minimum temperature (°C) and relative humidity (%) from transplanting to harvesting time under polyhouse conditions.

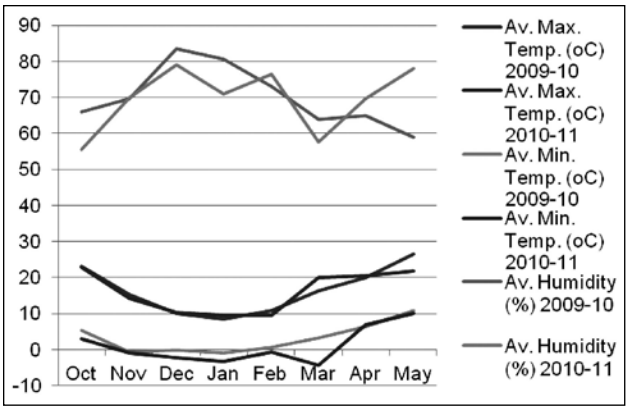

Fig. 2. Month-wise average maximum, minimum temperature (°C) and relative humidity (%) from transplanting to harvesting time under open conditions.

environments. Regardless of the cultivar these results indicate that polyhouse conditions protected strawberry plants from winter damage, provided a favourable climate for plant growth and produced earlier crop, however, the quality of the fruit was similar under both the growing conditions. Yield from the runners under field conditions was more than that of the runners growing under polyhouse. Hence, protected strawberry cultivation has a great potential for early production of quality fruits and protection from low temperatures, compared to the conventional strawberry production systems. In addition, early strawberries to the market can fetch a higher price in March or early April and contribute to farmer's profitability.

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