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Performance of six strawberry cultivars in tropical climate

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Abstract

Strawberry (*Fragaria* x *ananassa* Duch.) is one the most important fruits in the world. Its growth characteristics, yield and quality are severely affected by environmental conditions, cultivation area and cultivar. This study was conducted to evaluate the compatibility and yield comparison of six strawberry cultivars (‘Kordestan', ‘Parose', ‘Marak', ‘Queen', ‘Selva' and ‘Camarosa') in a tropical area known as "Gachsaran" in Iran. This trial was arranged in a completely randomized design. Vegetative and reproductive growth parameters like the number of flowers, fruits, leaves, leaf length and width were measured. In addition, fruit qualitative and quantitative parameters such as fruit volume, yield levels, the total soluble solid (TSS), juice acidity (TA), the sugar-acid ratio (TSS/TA), juice reaction (pH), vitamin C content and fruit firmness were determined. The results of variance analysis showed that the effects of cultivars on all parameters were significant. ‘Marak’ cultivar had the highest number of flowers, fruits, yield level, leaf length and width, but the highest total soluble solid (TSS), sugar-acid ratio (TSS/TA), and vitamin C content were related to Queen. Total acidity (TA), fruit firmness and juice reaction (pH) were significantly high in ‘Camarosa’ cultivar compared with the other cultivars.

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Introduction

Strawberry (*Fragaria* x *ananassa* Duch.) is an herbaceous, perennial plant with a compressed stem called the crown; leaves, flowers and stolons originated from the crown (Edmond *et al.*, 1977). Despite being native to temperate-zones, it has been introduced to other climate regions, where it grows and yields quite successfully upon adaptation. It also adapts readily under protected cropping conditions in many regions of the world. Strawberry growth and development is influenced by cultural, climate and physiological factors, and productivity in native lands is naturally controlled by distinct climate changes (Galleta and Himelrick, 1990). Determining precise cultural requirements for strawberry could enable growers to produce it extensively in new regions.

Temperature is important for floral initiation under short day (SD) conditions. The optimum temperature for SD floral initiation is 15–18 °C, while below 10 °C and above 25 °C SD induction is rather ineffective (Ito and Saito, 1962; Heide, 1977; Manakasem and Goodwin, 2001; Sonsteby and Heide, 2006; Verheul *et al.*, 2007). Although both day and night temperatures are of importance, the optimum night temperature depends on the prevailing day temperature and vice versa. Verheul *et al.*, (2007) thus found that flowering of some cultivars was as closely related to the average daily temperature as to day and night temperatures separately. Unfortunately, these authors limited their night temperature span in their experiment to 6–12 °C range.

It is a common notion among strawberry growers that flower bud formation in single-cropping cultivars is governed by low temperature and SD. Because of this, many growers are concerned about the effect of the predicted and ongoing global warming (Serreze *et al.*, 2000) on flower bud formation and yield of this crop. However, as we have seen, this low temperature is as high as 15–18 °C. Therefore, in the northern environment, temperature conditions during September when floral induction mainly takes place, is actually sub-optimal for SD induction in these plants. LeMiere *et al.*, (1996) concluded that even in Britain there is scope for increasing yield by increasing the temperature that plants receive during autumn. Badiyala and Bhutani (1990) and Pradeepkumar *et al.*, (2002) 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.

In this background, we have studied the effect of day/night high temperatures on some morphological and physico-chemical characteristics in six cultivars including ‘Kordestan', ‘Parose', ‘Marak', ‘Queen', ‘Selva' and ‘Camarosa' under controlled environmental conditions.

Materials and methods

Materials

The study was conducted at the Regional Agricultural Research Station, east of Gachsaran District situated at latitude 30° 20' north, longitude 50° 50' east and altitude of 710 m above sea level, in the Boyer Ahmad Province in Iran, to evaluate the performance of six cultivars of strawberry viz., ‘Kordestan' (short-day), ‘Parose' (short-day), ‘Marak' (day-neutral), ‘Queen' (short-day), ‘Selva' (day-neutral) and ‘Camarosa' (short-day). The tests revealed that soils at the site were well-drained clay to sandy loams. The rainfall received at the site ranges from 400 to 600 mm per annum and is bimodal; main rains fall from December to February.

The experiment was laid out in randomized block design with six cultivars and four replications. The station enjoyed a mild tropical weather with minimum temperature of 14 °C during night and maximum temperature of 36 °C during day. Plantings were carried out during the last week of September in the year of 2013, using runners of individual cultivars in plots of 4 x 4 m size and the spacing given was 40 x 30 cm. A basal dose of urea and potash 65:65 g per bed was applied. The same dose of chemical fertilizers was applied again 45 days after planting as topdressing. The plants were irrigated at 4-day intervals. During growth season, some parameters including number of leaves, leaf length and width, number flowers per plant, number of fruits per plant, berry fresh weight per plant, fruit volume, juice reaction (pH), berry's total soluble solid (TSS), total acidity, vitamin C content, fruit firmness and sugar-acid ratio (TSS/TA) were recorded.

Fruit firmness analysis

Firmness was measured as the maximum penetration force (N) reached during tissue breakage, and determined with an 8 mm diameter flat probe. The penetration depth was 5 mm and the cross-head speed was 5 mm s^{-1} using a TA-XT2 Texture Analyzer (Stable Micro Systems, Godalming,UK), MA. Strawberries were sliced into halves and each half was measured in the central zone. Fruit firmness values were an average of 25 strawberries.

Determination of biochemical quality attributes

After firmness analysis, strawberries were cut into small pieces and homogenized in a grinder, and 10 g of ground strawberry was suspended in 100 ml of distilled water and then filtered. The pH and titrable acidity of the samples were assessed using a pH meter (pH-526; WTW Measurement Systems, Wissenschaftlich, Technische Werkstatten GmbH, Wellhelm, Germany) and titrated to pH 8.1 using 0.1 M NaOH. Titrable acidity was expressed as grams of citric acid per 100 g of strawberry weight. The TSS was determined in the juice of ground strawberries by means of an Atago RX-1000 digital refract meter (Atago Co. Ltd., Tokyo, Japan) at 20 °C and expressed as a percentage. Measurements were done in triplicate. Total ascorbic acid (Vitamin C) was measured by the classical titration method using 2,6-dichlorophenolindophenol solution in mg/g tissue (Miller, 1998).

Statistical analyses

Analysis of variance was performed using the SAS software package and significant difference among the mean values was compared by Duncan test ($P<0.05$).

Results

Vegetative and reproductive parameters

The statistical analysis was carried out so as to determine the differences among six strawberry cultivars in response to tropical climate condition. The mean squares from analysis of variance (Table 1) revealed that main effect (cultivars) was significant for all the characters studied. The significance of cultivars indicated that varieties performed differently and also significantly affected the plant traits.

Table 1. Mean squares from analysis of variance for various physiological traits of strawberry cultivars grown under tropical climate.

Source of variance	Degrees of freedom	Mean squares						
		Number of flower	Number of fruit	Number of leaf	Yield per plant	Fruit volume	Leaf length	Leaf width
Block	3	0.77	0.59	0.7	38.92	0.75	0.007	0.001
Cultivar	5	3.76**	2.87**	2.27**	38.51**	3.18**	0.12**	0.13**
Error	15	0.41	0.36	0.8	45.46	0.49	0.01	0.04
Coefficient of variations		17.49	17.87	13.57	16.95	5.39	3.30	7.38

**: Significant at 1% probability level.

The results in table 2 show that 'Marak' cultivar significantly had the most number of flowers per plant, but had not a significant difference with 'Camarosa'. The lowest number of flowers is related to 'Selva'. 'Marak' and 'Camarosa' cultivars showed the significant highest number of fruits per plant, although there were no significant differences between them and 'Queen'. 'Selva' also had the lowest number of fruits compared with the other cultivars (Table 2). 'Marak', 'Kordestan', 'Queen' and 'Camarosa' showed no significant differences in number of leaves. 'Selva' had the lowest amount in this parameter, too. Results show that 'Marak' and 'Camarosa' significantly had the most leaf length comparing with the other cultivars. Leaf length decreased in 'Selva' and 'Queen' cultivars significantly (Table 2). 'Marak' also had the maximum leaf width, but no significant differences were observed between this cultivar and 'Kordestan', 'Selva' and 'Camarosa'. In this parameter, 'Queen' had the lowest unit, although it showed no significant differences with 'Kordestan', 'Parose' and 'Selva' (Table 2). On average, 'Marak' and 'Camarosa' significantly developed more yield per plant than the other cultivars. The decrease in the yield per plant was more pronounced in 'Selva', but had no significant differences with 'Kordestan' and 'Parose' (Table 2). Fruit volume was the highest for 'Selva' and 'Parose' when compared to 'Kordestan' and 'Queen' (Table 2).

Table 2. Physiological properties of strawberry cultivars grown under tropical climate.

Cultivars	Number of flowers/plant	Number of fruits/plant	Number of leaves/plant	Yield/plant (g)	Fruit volume (cm^3)	Leaf length (cm)	Leaf width (cm)
Kordestan	3.5 bc	3 bc	7.75 a	28.74 d	12.3 c	3.75 b	2.8 abc
Parose	3 cd	2.75 c	6.25 bc	36.23 cd	13.9 a	3.7 bc	2.7 cb
Marak	5 a	4.5 a	6.75 abc	54.27 a	13.57 ab	3.95 a	3.05 a
Queen	4 b	3.75 ab	7 ab	43.08 bc	11.93 c	3.55 cd	2.58 c
Selva	2.25 d	2.25 c	5.5 c	26.38 d	14.07 a	3.45 d	2.75 abc
Camarosa	4.25 ab	4 a	6.5 abc	50.05 ab	12.73 bc	3.76 ab	3 ab

Means in the same column with different letters are significantly different ($P<0.05$).

Biochemical compounds

Analysis of variance revealed that the cultivars had significant differences in biochemical characters at $P\leq0.01$ (Table 3). The percentage of TSS of 'Queen' was significantly more than the other cultivars. 'Selva', 'Kordestan', 'Marak', 'Parose' and 'Camarosa' significantly were at the lower levels, respectively (Table 4). 'Camarosa' significantly had the highest total acidity compared to the other cultivars. 'Selva' and 'Parose' were lower than 'Camarosa', and higher than 'Queen', 'Kordestan' and 'Marak', however they had no significant differences between each other. %TA decreased in 'Kordestan' and 'Marak' and significantly had the minimum amount in 'Marak' fruits (Table 4). Results in Table 3 shows that 'Queen' developed its flavor and significantly had the highest TSS/TA ratio. After that, flavor index (TSS/TA) was significantly decreased in 'Marak', 'Kordestan', 'Selva', 'Parose' and 'Camarosa', respectively. However, no significant difference was observed between 'Parose' and 'Camarosa' cultivars (Table 4). The highest vitamin C content was significantly observed in 'Queen' fruits. In contrast, 'Kordestan' and 'Marak' cultivars had the lowest vitamin C content. There was no significant difference between 'Parose' and 'Selva', and their vitamin C contents were among 'Queen' and 'Kordestan' and 'Marak' (Table 4). Analysis of means comparison indicated that fruits of 'Queen', 'Parose' and 'Camarosa' had higher pH than 'Kordestan', 'Selva' and 'Marak', but did not show significant differences.

Table 3. Mean squares from analysis of variance for various biochemical traits of strawberry cultivars

grown under tropical climate.

Source of variance	Degrees of freedom	Mean squares					
		Total soluble solid (TSS)	Total acidity (TA)	TSS/TA	Fruit firmness	Vitamin C	pH
Block	3	0.22	0.01	0.003	0.04	0.005	0.003
Cultivar	5	7.10**	4.00**	0.16**	0.33**	3.73**	0.025**
Error	15	0.07	0.04	0.001	0.01	0.003	0.01
Coefficient of variations		3.52	2.44	3.39	3.23	1.00	2.76

**: Significant at 1% probability level.

Fruit firmness

Results indicate that 'Camarosa' was more firm than the other cultivars. 'Kordestan' significantly had the lowest firmness. Differences in fruit firmness between 'Queen', 'Marak' and 'Parose' cultivars were not significant (Table 4).

Table 4. Biochemical properties of strawberry cultivars grown under tropical climate.

Cultivars	TSS (%)	TA (%)	TSS/TA	Fruit firmness (N)	Vitamin C (mg/100g juice)	pH
Kordestan	7.60 c	7.98 d	0.95 c	3.05 c	4.66 d	3.55 ab
Parose	6.38 d	9.08 b	0.70 e	3.65 b	6.16 b	3.68 a
Marak	7.38 c	6.85 e	1.08 b	3.75 ab	4.60 d	3.45 b
Queen	10.00 a	8.50 c	1.18 a	3.75 ab	7.05 a	3.62 a
Selva	8.05 b	9.23 b	0.87 d	3.73 ab	6.16 b	3.58 ab
Camarosa	6.43 d	9.58 a	0.67 e	3.85 a	5.28 c	3.64 a

Means in the same column with different letters are significantly different ($P<0.05$).

Discussion

The results demonstrate and underline the cultivation possibility of these strawberry cultivars in such tropical regions. Yet, the cvs. 'Selva', 'Queen', 'Parose', 'Kordestan' seemed to be more sensitive to photoperiod when compared to the cultivars 'Marak' and 'Camarosa'. In other words, tropical climate decreased the vegetative (number of leaves, leaf length and leaf width) and reproductive (number of flowers, number of fruits, mean of yield per plant) growth in these cultivars. However, 'Marak' and 'Camarosa' cultivars showed more adaptation to tropical regions and sensitivity to high temperature. They had noticeable vegetative and reproductive behaviors in tropical region. 'Kordestan' cultivar showed high acclimation to cold climate and had the highest yield in this region (Tehranifar and Sarsaefi, 2002) When growing strawberries in hot environments, attention must be paid to temperature and photoperiod patterns across all seasons, not just the summer. The strawberry is composed of several different meristems that are regulated by the interaction between photoperiod and temperature. Leaf development and root growth are also strongly regulated by temperature. Few cultivars exist that are specifically adapted to temperatures much above 30°C (Durner and Poling, 1988; Larson, 1994). In mild tropical climates, the short-day cultivars developed for temperate climates can be highly productive (Subramanium and Iyer, 1974); although flower bud formation is restricted if temperatures get too hot (Strik, 1985). In tropical highlands with short days and cool climates, short-day cultivars of

F. x ananassa performs similarly to day-neutrals in temperate climates, with cyclical patterns of flowering and fruiting. While short-day cultivars adapted to cooler climates can be grown in tropical and sub-tropical regions, they have a tendency to require a chilling period for full productivity. Those cultivars developed for warm regions may not need one. The ability to grow well during the short days of October, November and December in North American greenhouses has classically been used as an indicator of a cultivar's regional adaptation. Those adapted to cooler regions generally grow poorly during this period and enter a rest period, while those adapted to warmer climates continue to grow (Hancock, 2000).

While most cultivars are now categorized as day-neutrals or short-day plants, some genotypes are hard to rank precisely due to complex interactions between genotype, temperature and photoperiod (Yanagi and Oda, 1989). Galletta and Bringhurst (1990) have suggested that flowering in modern strawberry cultivars is regulated more by sensitivity to high temperature than photoperiod, with traditional short-day plants being more sensitive to high temperatures than day-neutrals. Results of the present experiment showed that temperature has an effect on the number of flowers per plant. Earlier experiments (Verheul *et al.*, 2006) showed that the number of inflorescences per plant was mainly influenced by plant age and the duration of short-day treatment. The effect of photoperiod and temperature is therefore mainly an effect on the number of plants that emerge flowers.

In the current experiment, the number of leaves and leaf growth showed various behaviors in different cultivars. Leaf production in both day-neutral and short day plants continues throughout the whole season, although leaf production and growth occurs most readily under long days (Nishizawa, 1990). Temperature optima range between 15-26°C, depending on cultivar (Abdelrahman, 1984). Arney (1953) found leaf initiation in 'Royal Sovereign' to be greatly reduced above 35°C. It has also been found that when plants are heat treated for virus elimination before propagation, they stop growing at 35-38°C, but if temperatures are raised a few degrees a day, leaves appear undamaged for at least 6 weeks (Converse, 1987).

Temperature had a marked effect on the number of flowers and fruits per plant. This is according to earlier findings in tomato (Atherton and Harris, 1986). Le Miere *et al.*, (1996) stated that temperature had little effect on the final number of flowers and found an upper limit of approximately 16 flowers in the primary inflorescence in strawberry cv. Elsanta.

Elevated air temperatures during fruiting have been shown to have a negative effect on fruit volume in sensitive cultivars. Went (1957) showed that daytime temperatures above 15-17°C reduced fruit size and fruit aroma, and optimal fruit growth occurred at 12°C night temperatures. Fruit volume in several day-neutral types in Maryland was about 50% smaller in the hot summer than cool spring (Draper *et at.,* 1981). Temperatures above 25°C can also reduce fruit set (Abdelrahman,1984), decrease fruit soluble solids content (Abdelrahman, 1984; Hellman and Travis, 1988) and increase the rate of fruit development (Darrow, 1966; Dana, 1980). Galletta *et al.* (1981) suggested that in day-neutral types, a decrease in soil temperature of 10°C can increase fruit size by 0.9 to 1.6 g/berry.

According to biochemical parameters, cultivars showed different actions in response to tropical climate. The differences between cultivars suggest that high temperature effect on strawberry chemical compositions is cultivar-dependent. The present results are in line with Hardh and Hardh (1977) who reported that sugar content was changed by high temperature. Higher growth temperatures caused development of fruit biochemical content more rapidly than that at lower growth temperatures. When the day/night temperature became warmer, the fruit TSS and flesh colors became more and redder (Galleta and Bringhurst, 1990). Higher growth temperatures significantly enhanced flavonol, acidic compound and total soluble solid content in strawberry fruit and juices, and also had high antioxidant activities (Wang and Zheng, 2001). The present data also in line with the results reported that soluble solids and citric acid varied considerably between the strawberry cultivars (Watson, *et al.*, 2002; Cordenunsi, *et al.*, 2005). The different cultivars tested in Gupta and Acharya (1993) study led to the difference in results of total soluble solids and acidity.

Strawberries are most commonly grown in hot climates by utilizing annual production systems that avoid the hot season. Since the cultivars represent a very narrow sample of the wild germplasm available (Sjulin and Dale, 1987; Luby *et al.,* 1991), it seems likely that new sources of heat tolerance can be found that could expand the heat tolerance of both short-day and day-neutral types. Finding new sources of heat tolerance in native day-neutral types may prove particularly useful in breeding for hot climates, as the existing germplasm pool is very limited.

Conclusion

'Marak' and 'Camarosa' cultivars are in general well adapted to high temperatures and can be introduced to such subtropical and tropical regions. Most floral and vegetative responses of these cultivars are significantly developed by high temperatures in excess of 35°C. However, for some susceptible cultivars, fall and winter planting systems may also be used in the warm climates that produce fruit during the cooler winter and early spring seasons and avoid summer heat. Native germplasm is probably available that can be cultivated and used by growers and breeders to increase the heat tolerance of the commercial strawberry, but this material is only in the early stages of evaluation.

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