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The Effects of Different Periods of Shading on Growth and Yield in 'Sweet Charlie' Strawberry

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Summary

In this study, the effects of shading treatments at different time periods on yield and growth in the Junebearing strawberry 'Sweet Charlie' were evaluated. The plants were covered with 50 % shading material in a greenhouse during the following periods: 1) greenhouse check (GC), no shade, 2) flower initiation period (FIP1) in Fall 2002, 3) flower initiation period (FIP2) in Fall 2002, 4) the fruiting period (FP) in Spring 2003, 5) constant shading (CS), 6) open field (OF), no shade. Shading during the FP reduced runnering. In general, there was no consistent effect of shading on the crown and leaf number in the experiment. The leaf area of the plants in the CS treatment was generally larger than that in the other treatments in the spring and summer period. Also, the petiole length of the plants in GC and CS was higher than that of the plants in OF in the spring and summer periods. Yield was significantly reduced in the FIP1 and FIP2 treatments. Shading during FP reduced inflorescence number and yield. CS significantly reduced all of the yield parameters. In OF, the number of inflorescences and flowers and the yield per plant was significantly reduced compared to other treatments possibly because of lower temperature preventing flowering or injuring the flowers. The increased fruit weight with CS and OF treatments was the result of reduced inflorescence and flower numbers. Fruit was the smallest in FIP1. The soluble solid content of the fruits in OF was the highest possibly due to the high light intensity while those of the fruits in CS and FP was the lowest. The amount of discarded fruit (deformed, rotten and small fruit) on plants shaded during FP was the highest while the least amount of total discarded fruit was from plants in the open field. In summary, the results of the study suggest that 'Sweet Charlie' responded negatively to shading.

Key words. shading – growth – strawberry – 'Sweet Charlie' – quality – yield

Introduction

Short day treatments (generally 8–12 h) are needed to optimise the flowering of many strawberry cultivars classified as June-bearers. It has also been known that dark or short day treatments at the end of the summer increase flower formation and yield in June-bearers (Ito and Saito 1962; Shishido et al. 1990; Austin 1991; Paydas and Kaska 1991; Kanmaz 1995; Sonsteby 1997; Konsin et al. 2001, 2002). However, the information on the influence of decreased light levels on flower initiation and growth in the strawberry is limited. Smeets (1976) reported that there was stamen abortion under low light conditions in 'Glasa' strawberry. Constant shading and shading during the fruiting period with a shading material (60 %) in 'Earliglow' decreased leaf dry weight and yield; shading during the spring growth and fruiting period delayed peak harvest by 2 to 7 days (Ferree and Stang 1988). Shading (70 %) in 'Bokyojosaeng' resulted in flower bud differentiation that was 4 days early (Ra et al. 1992). Constant shading during 44 days was more effective than chilling on the flower bud formation in 'Nyoho' (Kumakura and Shishido 1993). Awang and Atherton (1995) suggested that shading decreased leaf area and number. In strawberries grown in constant dark, the leaf stalk was long, the leaf area was small and chlorophyll and carbohydrate contents were low (Nishizawa et al. 1999; Shishido et al. 1999). Some research revealed that shading during the flowering period was effective in increasing the shelf-life of the fruit (Osman et al. 1992); shading during the fruit growth period decreased acidity and soluble solid after storing in a controlled atmosphere (Osman and Dodd 1994), and the effect of reduced light levels during the flowering period on acidity and soluble solid was small or absent (Hansen 1996).

In Turkey, the output of the early cultivar 'Sweet Charlie' is second behind 'Camarosa'. So, it is an important cultivar in strawberry production. The study aimed to determine the effects of shading treatments at different time periods in 'Sweet Charlie' strawberry on growth, yield and fruit quality.

Material and Methods

On 1 August 2002, frigo plants of the 'Sweet Charlie' strawberry were planted in double-row plots with a 30 x 30 cm spacing in a triangle planting system in a plastic greenhouse with side ventilation gaps and in an open field. Plots were established on peat, manure and garden

soil mixture (1:1:3). Conventional fertilizer (ammonium sulphate, 3 g plant^{-1}) was applied on the 26 Aug. and the 20 March. The chemical properties of plant growth media were: pH=7.35; $EC_{25\,°C}$=0.36 dSm^{-1}; organic matter= 6.03 %; total N=0.302 %; Available P=162.9 mg kg^{-1}; Exchangeable K=776.86 mg kg^{-1}; Exchangeable Ca= 21.26 meq 100^{-1}; $CaCO_3$=2.77 %. Conventional pest control sprays that are recommended were applied to all the treatments throughout the experiment. The experiment was arranged in a randomised complete block design with five treatments, four blocks per treatment, and 30 plants per block. A total of 120 plants per treatment were used. A commercial shading material (50 % shade) for shading treatments was stretched across frames to enclose the sides, top and ends of the plots including each treatment during each of the treatment periods. The treatments included:

1) greenhouse check (GC), no shade,
2) the approximate flower initiation period in fall 2002 (FIP1) (greenhouse), from Aug.15th–Sep.15th,
3) the approximate flower initiation period in fall 2002 (FIP2) (greenhouse), from Sep.1th–30th,
4) fruiting period (FP) in spring 2003 (greenhouse), from Apr.21th– the end of the harvest,
5) constant shading (CS) (greenhouse),
6) open field (OF) (no shade).

Temperature and relative humidity were measured at weekly intervals by a digital thermograph (Table 1). Light intensity was measured at one week intervals by the Delta-T Devices SS1 Sun Scan Canopy Analyser (Fig. 1). Light measurements were performed at the bottom of the plants from four different points, each 5 cm apart, as well as one measurement about 20 cm above the plant canopy. The shading level and the shading material of the FIP1 and the FIP2 were the same as for the CS. And also shading time of these treatments coincided with that for the

Table 1. Temperature (°C) and relative humidity (%) condition for each treatment.

Treatments		Days after planting							
		39 (9 Sep)	77 (17 Oct.)	123 (2 Nov.)	172 (20 Jan.)	221 (10 Mar.)	270 (28 Apr.)	319 (16 June)	368 (4 Aug.)
GC	Temperature	21,3	20,6	13,6	8,7	8,5	14,6	24,5	25,6
	Humidity	83,1	75,7	66,4	65,5	75,7	52,9	62,4	78,1
FIP1	Temperature	21,5	21,0	14,0	8,7	9,3	14,7	24,7	25,9
	Humidity	86,2	75,3	66,3	71,9	71,4	57,2	65,3	71,9
FIP2	Temperature	21,5	20,6	14,3	8,9	9,4	14,7	24,8	25,5
	Humidity	84,5	75,8	67,2	68,9	73,8	56,2	63,0	72,3
FP	Temperature	–	–	–	–	–	14,4	24,2	25,5
	Humidity	–	–	–	–	–	53,8	64,7	75,6
CS	Temperature	21,3	21,2	14,1	8,4	9,5	15,3	25,1	26,4
	Humidity	86,0	77,5	69,2	73,2	69,9	60,3	67,9	73,2
OF	Temperature	20,0	18,7	9,8	5,6	4,9	9,9	22,6	24,6
	Humidity	83,5	74,1	48,9	39,5	68,2	50,8	64,2	71,7

GC: Greenhouse check; FIP1: Flower initiation period in fall, 15 Aug.–15 Sept.; FIP2: Flower initiation period in fall, 1–30 Sept.; FP: Fruiting period, 21 Apr.–end of the harvest; CS: Constant shading; OF: Open field, no shade.

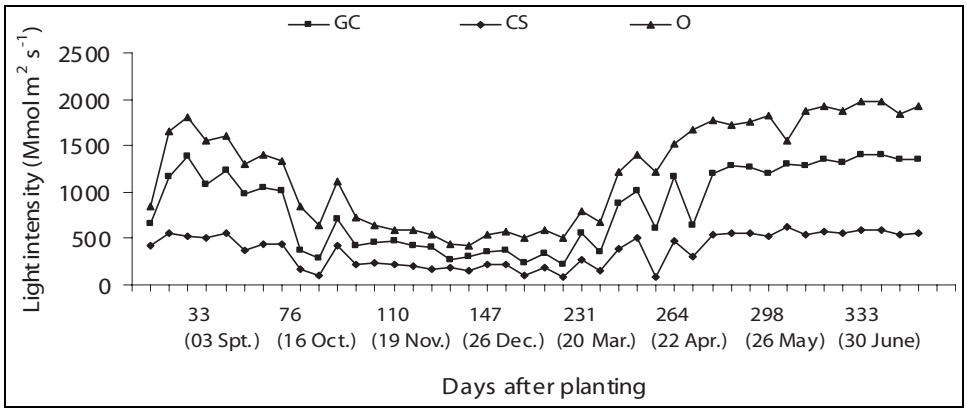


Fig. 1. Light intensity condition for each treatment.

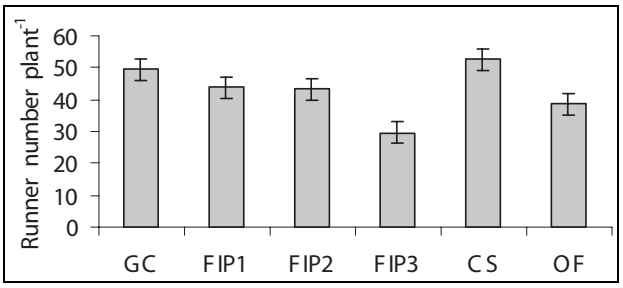


Fig. 2. Effects of shading treatments on runner number (vertical bars ± SE).

CS. For this reason, extra light intensity data for these treatments was not given.

Vegetative growth

Runners were counted during springtime following planting and were removed afterwards. Vegetative growth parameters, but not runner growth were assessed at only three treatments namely the greenhouse check, constant shading and open field. Three plants were pulled up from each treatment throughout the harvest at 20-day intervals starting from planting except during the dormancy period (6 Jan.–17 Mar.). The crown number, the leaf number, the leaf area using a planimeter and leaf stalk length of the plants pulled up were measured.

Flower Production, Yield, and Fruit Quality

First the bloom, fruit set and harvest dates were recorded. Inflorescences and flower numbers were counted on five plants from each replicate of all the treatments. Yield (g plant^{-1}) was determined by counting and weighing the fruits of those plants pulled up from each replicate of each treatment during the harvest season. Fruit weight (g), TSS (Total Soluble Solids) and acidity were determined. The last by titration with 0.1 NaOH (as equivalent of citric acid). In addition, discarded fruits including deformed, rotten and small fruits were also determined. Fruits being smaller than 5 g were described as small fruit.

Results and Discussion

Vegetative growth

Shading during the fruiting period (FP) reduced runnering by as much as 40 % compared to the GC (Fig. 2). This is possibly a response to reduced light intensity during the early stage of the runnering period (Fig. 1). In previous studies, it was reported that the runner production increased with increasing light intensity under controlled greenhouse conditions (SMEETS 1955) and that the effects of increasing light intensity on runner production were quantitative (DENNIS et al. 1970). Runner counts in the greenhouse check (GC) and constant shading (CS) were more than those in the other treatments. While increased runner counts in CS may be explained by a low yield, increased runner counts in GC in spite of the high fruit production may be due to higher light intensity (Fig. 1). DARROW (1965) and MANAKASEM and GOODWIN (2001) emphasized that there is a negative relationship between runner formation and yield.

In general, there was no significant difference between GC and CS in terms of the crown (except for in the last two dates) and leaf numbers of the plants (Fig. 3). FLETCHER et al. (2002) explained that vegetative growth (leaf number, leaf area, leaf fresh and dry weight) was reduced with increasing shading (31, 48 and 63 %). However, such an effect was not present in our experiment. This may have originated from the relatively low level of shading (50 %). The crown and leaf number were generally lower in the OF than GC and CS as a result of low temperatures (Table 1). This also explains the low yield in the OF. Likewise, the leaf and crown numbers of the strawberry are closely associated with the yield potential (MIERE et al. 1998; MORROW and DARROW 1940).

In autumn, the leaf area of the plants in the CS and GC was generally higher than those of the OF. In spring and summer, the leaf area of the plants in the CS was generally higher than that in the others (Fig. 3). In the autumn and winter period, there was a slight difference between OF and the other treatments in terms of petiole length. However, in the spring and summer growth period, petiole length of the plants in the GC and CS (Fig. 3) was similar to each other and significantly higher than those of the plants in the open field because of high humidity (Table 1) as reported by LIETEN (2002) and the low light intensity (Fig. 1) in the

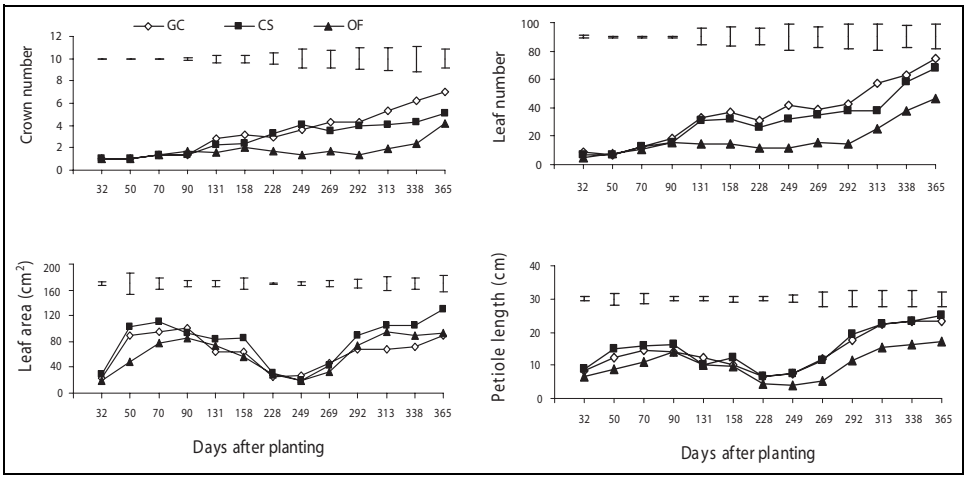


Fig. 3. Effects of the treatments on varying of crown number, leaf number, leaf area and petiole length. Vertical bars on graph represent the standard error of the difference for each dissection. Days after planting: 32nd: 2 Sep.; 50th: 20 Sep.; 70th: 10 Oct.; 90th: 30 Oct.; 131st: 10 Dec.; 158th: 6 Jan.; 228th: 17 Mar. ; 249th: 7 Apr.; 269th: 27 Apr.; 292nd: 20 May; 313th: 10 June; 338th: 5 July; 365th: 1 Aug.

Table 2. First flowering, fruit set and harvest dates in the different shading treatments.

Treatments	First flowering	Fruit set	First harvest
GC	30 March	06 April	29 April
FIP1	18 March	27 March	24 April
FIP2	15 March	27 March	24 April
FP	30 March	06 April	24 April
CS	05 April	20 April	06 May
OF	15 April	05 May	20 May

GC: Greenhouse check; FIP1: Flower initiation period in fall, 15 Aug.–15 Sept.; FIP2: Flower initiation period in fall, 1–30 Sept.; FP: Fruiting period, 21 Apr.–end of the harvest; CS: Constant shading; OF: Open field, no shade.

greenhouse. FERREE and STANG (1988) reported that petiole length was increased by constant shade, and excavation of an extra replication of plants following each period of shading revealed that leaf size generally increased with shading. Likewise, SHISHIDO et al. (1999) and NISHIZAWA et al. (1999) reported that the petiole length of the plants grown in the dark were longer. This also was not consistently observed clearly in our experiment.

Flower Production, Yield and Fruit Quality

The first flowering was observed between the 15th Mar. and the 15th Apr. Fruit set occurred between the 6th Apr. and the 5th May. The first harvest date was between the 29th Apr. and the 20th May. The latest flowering, fruit set and ripening occurred in the open field because of the low temperature (Table 1). Also, constant shading delayed flowering, fruit set and fruit ripening (Table 2). FERREE and STANG (1988) put forward that shading during the spring growth and fruiting period delayed fruit maturity by 5–7 days, possibly resulting from reduced temperatures under the shaded canopy. In the present experiment, there was no a significant temperature difference among treatments in the greenhouse. Therefore, this effect may result from the effects of shading on plant morphology and physiology. Likewise, shading reduced vegetative growth, chlorophyll and carbohydrate contents (AWANG and ATHERTON 1995; NISHIZAWA et al. 1999; SHISHIDO et al. 1999). Flowering and ripening in FIP1 and FIP2 were 12–15 days and 5 days early, respectively, compared to the GC. Shading during the flower initiation periods may have provided early flowering, possibly giving preference to flower bud formation with altering critical day length and light intensity for flower initiation. SHISHIDO et al. (1990) and RA et al. (1992) reported, that the shading and dark treatments gave preference to bud formation and flowering.

All of the treatments reduced the number of inflorescences compared to the GC (Table 3). Inflorescence number and yield were significantly reduced by FIP1 and FIP2 treatments. However, both treatments did not affect flower number. FERREE and STANG (1988) reported that shading during flower formation in Ohio reduced the yield, which is in agreement with our observations in the present study. In contrast to this case, in 'Camarosa', OZTURK and DEMIRSOY (2004) reported that the shadings during the flower bud formation periods increased inflorescence, flower number and yield, possibly because of the shortening day length. Besides, there are the reports that short day treatment in the bud formation period increased yield (SMEETS 1982; DURNER et al. 1984) and shading prior to constant dark and low temperature promoted flower bud formation (KUMAKURA and SHISHIDO 1993). These observations imply that the response of 'Sweet Charlie' to shading is negative. In other words, the response of the 'Sweet Charlie' to shadings during the 15th August–30th September was a low yield. In 'Sweet Charlie', the critical day length and light level needed for flower bud formation may be high. A study on growth and development in three strawberry in North Carolina suggested that the 'Sweet Charlie' originating from Florida showed lower dry matter accumulation, relative growth and yield than 'Chandler' and 'Camarosa' originating from California. And, it was reported that 'Sweet Charlie' might not be well adapted to North Carolina and needed different management strategies (FERNANDEZ et al. 2001). In the present experiment, the shading treatment in the FP reduced inflorescence number and yield (Table 3). FERREE and STANG (1988) reported that shadings in early spring and the fruiting period significantly reduced yield. AWANG and ATHERTON (1995) suggested that shading decreased inflorescence number and yield. SMEETS (1976) determined that low light prior to flower opening caused stamen abortion and poor fruit set. Also, SMEETS (1980) reported that high light intensity increased the proportion of flower with a well-formed stamen, the proportion of

Table 3. The effects of different shading treatments on inflorescences and flower number, yield, fruit weight, soluble solid and acidity.

Treatments	Inflorescence plant^{-1}	Flower plant^{-1}	Yield (g plant^{-1})	Fruit weight (g)	Soluble solid (%)	Acidity (%)
Greenhouse check	17.4 a[Z]	93.1 a	1014.8 a	10.2 ab	6.8 bc	0.52 b
Flower initiation period 1	15.8 ab	86.6 a	870.3 b	9.3 b	7.2 b	0.50 b
Flower initiation period 2	15.7 ab	90.3 a	906.9 b	9.9 ab	7.3 b	0.50 b
Fruiting period	13.6 b	76.7 a	630.7 c	10.2 ab	6.2 c	0.50 b
Constant shading	10.2 c	57.2 b	710.9 c	11.2 a	6.4 c	0.55 b
Open field	6.0 d	34.2 c	239.0 d	11.1 a	8.2 a	0.70 a

[Z]Mean separation by Duncan's multiple test, 5 % level

Table 4. Effects of shading treatments on rotten fruit, deformed fruit, small fruit and total discarded fruit.

Treatments	Total discarded fruit (g plant^{-1})	Rotten fruit (g plant^{-1})	Deformed fruit (g plant^{-1})	Small fruit (g plant^{-1})
Greenhouse check	61.26 b	38.12 b	2.06 bc	21.58 ab
Flower initiation period 1	48.43 c	18.49 c	4.73 ab	26.38 a
Flower initiation period 2	51.40 bc	27.11 c	5.48 a	18.80 b
Fruiting period	76.22 a	66.32 a	4.69 ab	5.20 c
Constant shading	55.43 bc	46.40 b	3.74 abc	7.03 c
Open field	7.13 d	4.44 d	0.48 c	2.2 c

[Z]Mean separation by Duncan's multiple test, 5 % level

fruit set, the inflorescence number and the flower number/inflorescence in 'Glasa'. These references may explain low yield in the FP. In the experiments, constant shading significantly reduced all of the yield parameters, probably as a result of low illumination over a long period (Fig. 1). Ferree and Stang (1988) in 'Earliglow' and Ozturk and Demirsoy (2004) in 'Camarosa' reported similar observations. In the plants in the open field, the number of inflorescences and flowers and yield per plant were significantly reduced compared to other treatments possibly, because of lower temperature and humidity (Table 1) which prevented flowering or injuring the flowers.

There were significant differences among the treatments in terms of fruit weight. Increased fruit weight with constant shading and open field treatments was a result of a reduced number of inflorescences, flowers and yield (Table 3). Similar results were determined by Ozturk and Demirsoy (2004) in 'Camarosa'. Besides, Ferree and Stang (1988) reported that increased berry weight with constant shading was concomitant with a reduced number of fruit. The fruits were the smallest at FIP1.

While soluble solid content of the fruits in the open field was the highest possibly due to high light intensity and the high temperature difference between daylight and night, the soluble solid content of the fruits in the CS and FP was the lowest, possibly due to low light intensity (Fig. 3). Osman et al. (1992) reported that shading from flowering did not affect TSS and acidity content to the end of the harvest. Acidity was higher in fruits of plants in the open field than those in the other treatments (Table 3).

The amount of discarded fruit (rotten, deformed and small fruit) was highest from plants in the FP treatment, followed by those from the GC (Table 4). Fletcher et al. (2002) reported that shading during the green-fruit stage increased unmarketable fruit. Ferree and Stang (1988) determined that shading during the fruiting period reduced total usable fruits (showing no rot, insect injury, or malformation). CS, FIP2 and FIP1 treatments reduced the total amount of discarded fruit compared to GC, and was depended a reduction in yield. The least amount of discarded fruit was from the plants in the open field because in the later harvest. There was good pollination and fruit set because of increasing temperature and low humidity. And also, airing in the open field was better because of poor vegetative growing which was a result of low temperatures (Table 1). The quantity of fruit with grey mould (rotten fruit) was the highest from plants shaded during FP and CS because of the relatively low illumination and high humidity under the shading material and highest during GC because of poor airing depending on vigorous vegetative growth under greenhouse conditions and greenhouse type. Deformed fruit was increased in all treatments in the greenhouse. It was reduced in the open field due to late flowering; thus, pollination and fertilization increased with increasing temperature in this period. The amount of small fruit was reduced in OF, CS and FP while it was increased in FIP1, FIP2 and GC, and was dependent upon yield (Table 4).

The yield in Apr. was not shown in Fig. 4 because it was very low. Peak harvest was in May. In this month, maximum crop was obtained from GC and FIP1. Constant shading treatments reduced the yield in May. The lowest yield was obtained from OF in May. In June, the highest yield was from OF (due to a late harvest) and FIP2 (Fig. 4). The

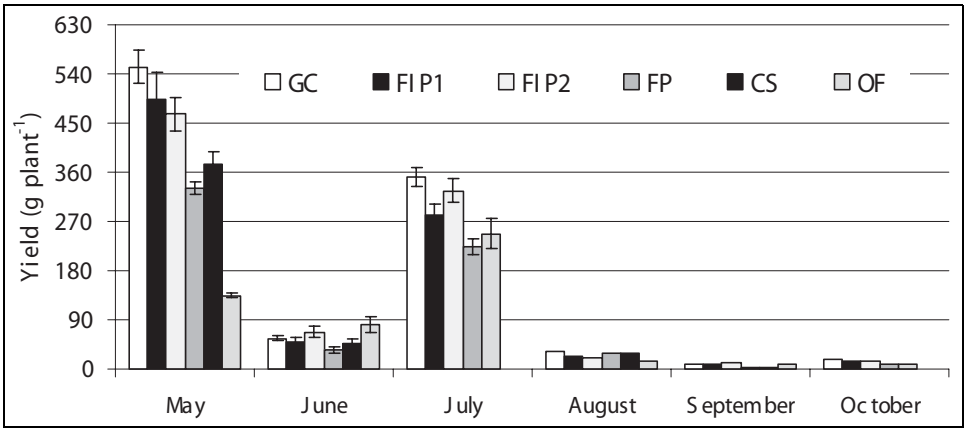


Fig. 4. Effects of shading treatments on yield as harvest season (GC: Greenhouse Check, no shade; FIP1: the approximate flower initiation period in fall, 15 Aug.–15 Sept.; FIP2: approximate flower initiation period in fall, 1–30 Sept.; FP: fruiting period, 21 Apr.–end of the harvest; CS: constant shading ; OF: open field, no shade (vertical bars ± SE).

second crop was obtained from all treatments except from the OF in July. However, yield in July was lower than that of May. The highest yield was from GC and FIP2 in July. In addition, a small amount of crop was also harvested from all treatments in Aug., Sept. and Oct.

In Turkey, 'Sweet Charlie' is an earlier cultivar commonly used in strawberry production. And also, its harvest period extends from March to October. Suitable management techniques may increase yield and quality in 'Sweet Charlie'. In the present study, it was shown that 'Sweet Charlie' responded negatively to shading in different periods of plant growth (less production, but in some cases reduced discarded fruit). Shadings during approximate flower initiation periods resulted in an earlier flowering and harvest time, possibly because of altering critical day length and light levels for flower initiation. But, reduction of the yield with shading during approximate flower initiation periods was interesting when compared with 'Camarosa' shaded in the same flower initiation periods (Ozturk and Demirsoy 2004) and some other cultivars applied short day in bud formation period (Ito and Saito 1962; Austin 1991; Paydas and Kaska 1991; Kanmaz 1995). The flower initiation period should be precisely determined in the 'Sweet Charlie' and the effects of shading during this time should be examined as the subject of a further study.

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