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Seasonal variation of N, P, K and Ca content of leaf, crown and root of 'Sweet Charlie' strawberry under different irradiation

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Abstract

The current study was designed to determine the seasonal dynamics of mineral nutrient contents (N, P, K and Ca) in the leaf, crown, and root under different irradiation in the strawberry cultivar 'Sweet Charlie'. The experiment involved three treatments: greenhouse check (GC), constant shading (CS), and open field (OF). Leaf, crown, and root samples were obtained from the plants at different growth stages, and mineral contents were determined by the standard method of dry ashing. The contents of all elements tested were expressed in % dry weight. The nutrient contents in leaf, crown and root changed according to different treatments and plant growth periods. In general, N, P and K contents in all treatments decreased during flowering and harvest period since they were used for fruit. Calcium uptake showed a peak at the time of flowering and during fruit ripening because of increasing temperature. Nutrient contents in individual plant organs in OF was lower than in CS and GC during the experiment.

Key words: strawberry, mineral elements, seasonal variation, irradiation.

Introduction

Strawberry has been widely grown worldwide because of its ability to adapt to various ecological conditions. Prerequisites for a successful strawberry yield are climate and soil. Specific nutrient management practices are required for individual cultivars grown under these widely different environmental conditions to ensure large yields of quality fruit (May, Pritts, 1990).

N, P, K, and Ca are very important mineral elements in strawberry growing (Kessel, 2003). Nitrogen is used for producing proteins, nucleic acid, and various coenzymes. Phosphorus is effective in energy transfer process in plants. Potassium influences uptake of carbon dioxide and photosynthesis, and regulates opening of stomata (May, Pritts, 1990). Calcium provides maintenance of membrane integrity and wall structure, and acts as a secondary messenger in metabolic regulation (Kessel, 2003).

A good nutrition program for strawberry is important in terms of yield, fruit quality, and in preventing environmental pollution and wasteful expenditure. For this reason, it is important to know the factors affecting nutrient availability and uptake. The range of climates, soil physicochemical conditions, genotypes, and cultural practices affect nutrient uptake from soil (Mengel, Kirkby, 1982). To develop sound nutritional programs for optimal strawberry production, cultural, climatic and plant growth media factors must be considered together with an understanding of physiological role each element plays in the growth and development of plant (May, Pritts, 1990).

There is a relationship between light requirement of plant and soil fertility. Leaves of plants growing on fertile soil contain more chlorophyll, so these bring about more photosynthesis. Light causes the opening of stomata and more transpiration. Thus, the plant uptakes more water and minerals (Barker, Pilbeam, 2006). Although many studies investigating the relationship between plant growth and lighting have been carried out, studies showing the relationship between nutrient contents and reducing light levels are rare. Under different light conditions, some important physiological and

biochemical changes occur in the leaf, crown, and root of strawberry. These changes may considerably affect nutrient accumulation as well as the yield and quality of strawberry. Therefore, the present study was designed to investigate seasonal variation of contents of major nutrients (N, P, K and Ca) in strawberry plant organs (root, crown, and leaf) in greenhouse conditions and open field.

Materials and methods

Chemical analysis of plant growth media. Plots were established on peat, cow manure, and garden soil mixture in a 1:1:1 ratio (v/v/v). Chemical analyses were conducted on air-dried samples wherein crop residues, root fragments, and rocks larger than 2 mm had been removed. Selected chemical properties were determined by means of appropriate methods: particle pH in 1:2.5 (w/v) in plant growth media (PGM), water suspension by pH-meter; $CaCO_3$ content by Scheibler calcimeter, electrical conductivity (EC) in 1:2.5 (w/v) in PGM, water suspension by EC-meter, total nitrogen by Kjeldahl method, available P by the 0.5 M $NaHCO_3$ extraction, and exchangeable K and Ca by the 1N NH_4OAc extraction. Whole soil samples were sieved through a 150-μm mesh to determine total organic carbon by the wet oxidation method (Walkley-Black) with $K_2Cr_2O_7$ (Rowell, 1994; Jones, 2001).

Experimental design. On 1 August, frigo seedlings of 'Sweet Charlie' cultivar were planted in double-row plots at 30 x 30 cm spacing in a triangle planting system in a plastic greenhouse and open field in Samsun, Turkey. The experiment was arranged in a randomized complete block design with three treatments and four blocks giving a total of 30 plants per block for each treatment. A total of 120 plants per treatment were used. The treatments included greenhouse check (GC), constant shading (CS), and open field (OF). The plants in constant shading treatment were covered with commercial dark green shade material with holes and 50% transmittance. The sides, top, and ends of the treatment were enclosed with shading material during the treatment period. It was established to bottom of plastic greenhouse cover. There was no shading material except for plastic greenhouse cover in greenhouse check treatment. The plants were watered by dripping system and mulched with straw. Conventional fertilizer was applied with ammonium sulfate (3g $(NH_4)_2SO_4$/plant) 26 August and 20 March.

Three plants were pulled up from each treatment on the following dates: (1) 90 days after planting (30th October), (2) 131 days after planting (10th December), (3) 158 days after planting (6th January), (4) 228 days after planting (17th March), (5) 292 days after planting (20th May), and (6) 338 days after planting (5th July). Some phenological observations such as first flowering, fruit set and harvest dates, and yield of 'Sweet Charlie' strawberry, are given in Table 1.

Temperature and light measurements: air and soil temperature by a digital thermograph, and light intensity by a Sun Scan Canopy Analyzer (Delta-T Devices SS1) were measured according to Demirsoy et al. (2007) and Kandemir (2005). 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.

Table 1. First flowering, fruit set and harvest dates in the different treatments

Treatments	First flowering	Fruit set	First harvest	Yield (g/plant)
Greenhouse check (GC)	30 March	06 April	29 April	1014.8
Constant shading (CS)	05 April	20 April	06 May	710.9
Open field (OF)	15 April	05 May	20 May	239.0

Nutrient (N, P, K and Ca) contents in plants. The plants were separated into roots, crowns, and leaves with petioles, and were washed. Plant materials were oven-dried at +70°C. Total nitrogen was determined by the Kjeldahl method. Dried and homogenized plant materials were dry-digested and then P concentration in the solutions was determined by ammonium heptamolybdate-ammonium vanadate in nitric acid method with a spectrophotometer. Potassium and calcium concentrations of plant materials were determined after dry-digestion using an atomic absorption spectrometer (Perkin-Elmer A400) with flame (Jones, 2001).

Statistical analyses. All data were analyzed using SPSS 16.0 statistical software (SPSS Inc.). Analysis of variance was performed to compare differences; where significant, *F*-values were obtained; differences between individual means were tested using the Duncan's multiple comparison tests. All the figures presented include standard error of the data and *F*-values.

Results and discussion

Physicochemical properties of plant growth media (PGM) are given in Table 2. The results showed that PGM are slightly alkaline (pH 7.3–7.8), high (>5%) in organic matter content, low (<5%) in $CaCO_3$ content, high (>0.25%) in total nitrogen, high (<18 µg g^{-1}) in phosphorus, high (>2 cmol kg^{-1}) in potassium, high (>20 cmol kg^{-1}) in calcium, and non-saline (<2 dS m^{-1}) according to Hazelton and Murphy (2007). Air and soil temperature, light intensity and photoperiod data are given in Figure 1.

Table 2. Chemical properties of plant growth media

pH	$CaCO_3$ %	EC 25°C dS m^{-1}	N %	P µg g^{-1}	K cmol kg^{-1}	Ca cmol kg^{-1}	Organic matter %
7.35	2.77	0.36	0.302	162.9	19.91	21.26	6.03

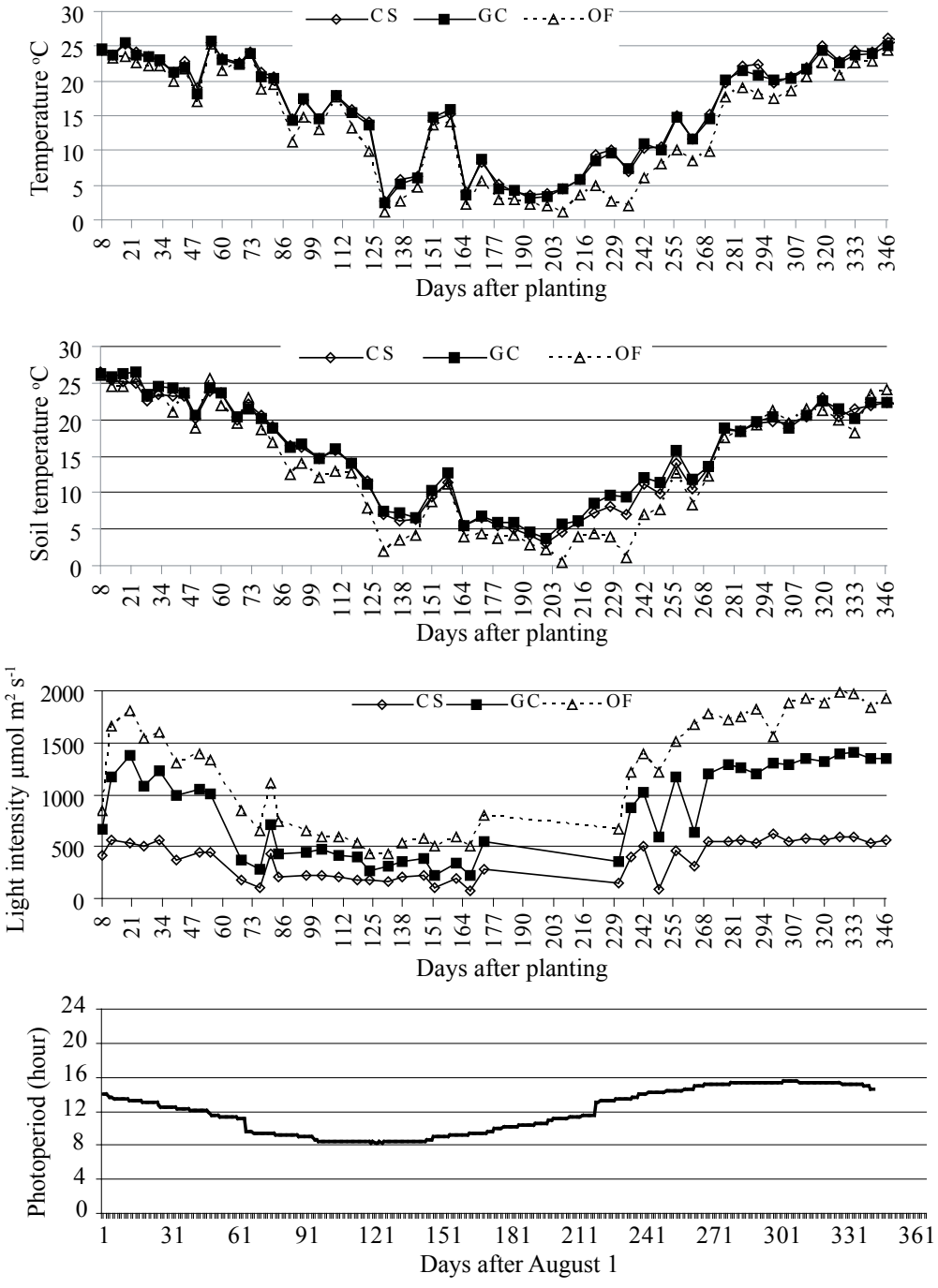
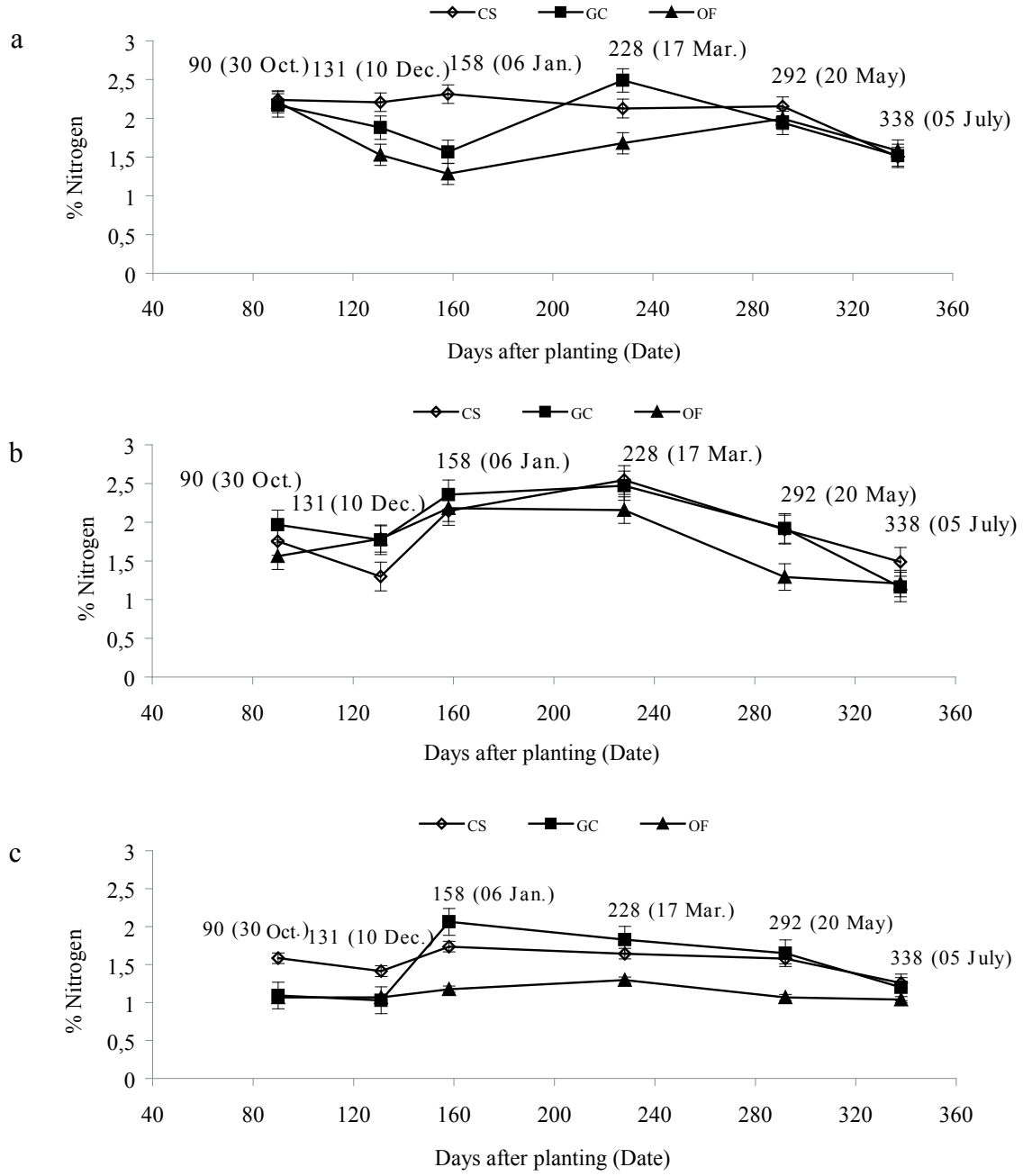


Figure 1. Air and soil temperature, light intensity and photoperiod of experiment sites (GC – greenhouse control, CS – constant shading, OF – open field)

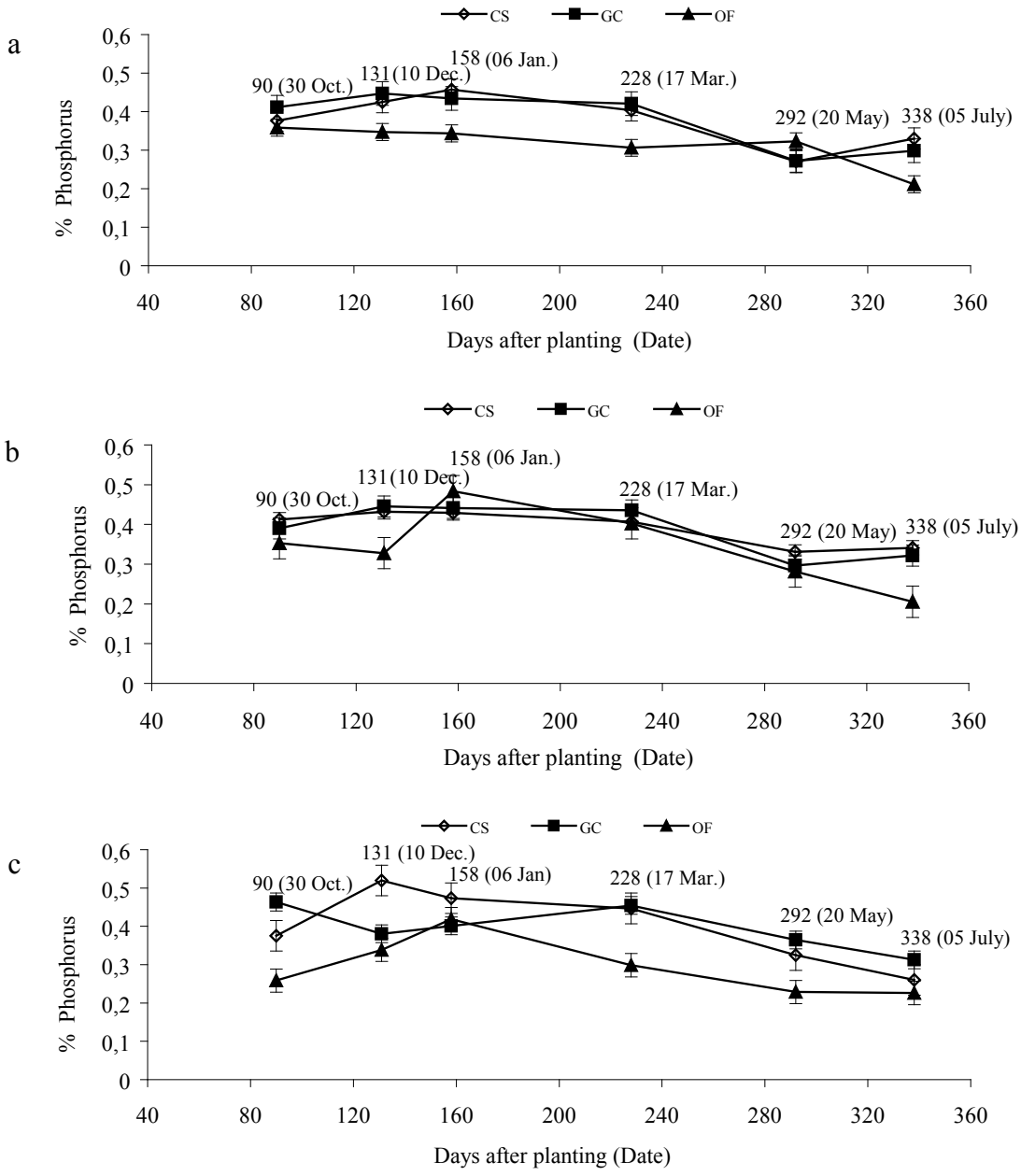
The results of this study showed that there were considerable variations in all nutrients, N, P, K and Ca, for the different parts of plant, different treatments (GC, CS, and OF) and plant harvest dates (Figure 2, 3, 4, 5).



Note. Vertical bars on graph represent the standard error of the difference for each dissection.
The experimental treatments: GC – greenhouse control, CS – constant shading, OF – open field;
T – treatment, D – days, ns – non significant.

Figure 2. N variation in leaf (F value: T = 3.48*, D = 3.07*, T × D = 1.18 ns) [a], crown (F value: T = 7.37**, D = 35.8***, T × D = 2.63 ns) [b], root (F value: T = 37.25***, D = 16.88***, T × D = 5.16***) [c] of 'Sweet Charlie' strawberry under different irradiation.

Nitrogen content in leaves generally decreased in GC and OF and stayed stable in CS treatment during autumn in cv. 'Sweet Charlie' (Fig. 2). Human and Kotze (1990) reported that nutrient uptake was not very active during the late autumn and winter in cv. 'Selekta'. Foliar N increased from dormancy through the beginning of the vegetative growth in GC and OF, while it generally decreased during fruit growing period and harvest in all treatments, except for increasing between 228–292nd

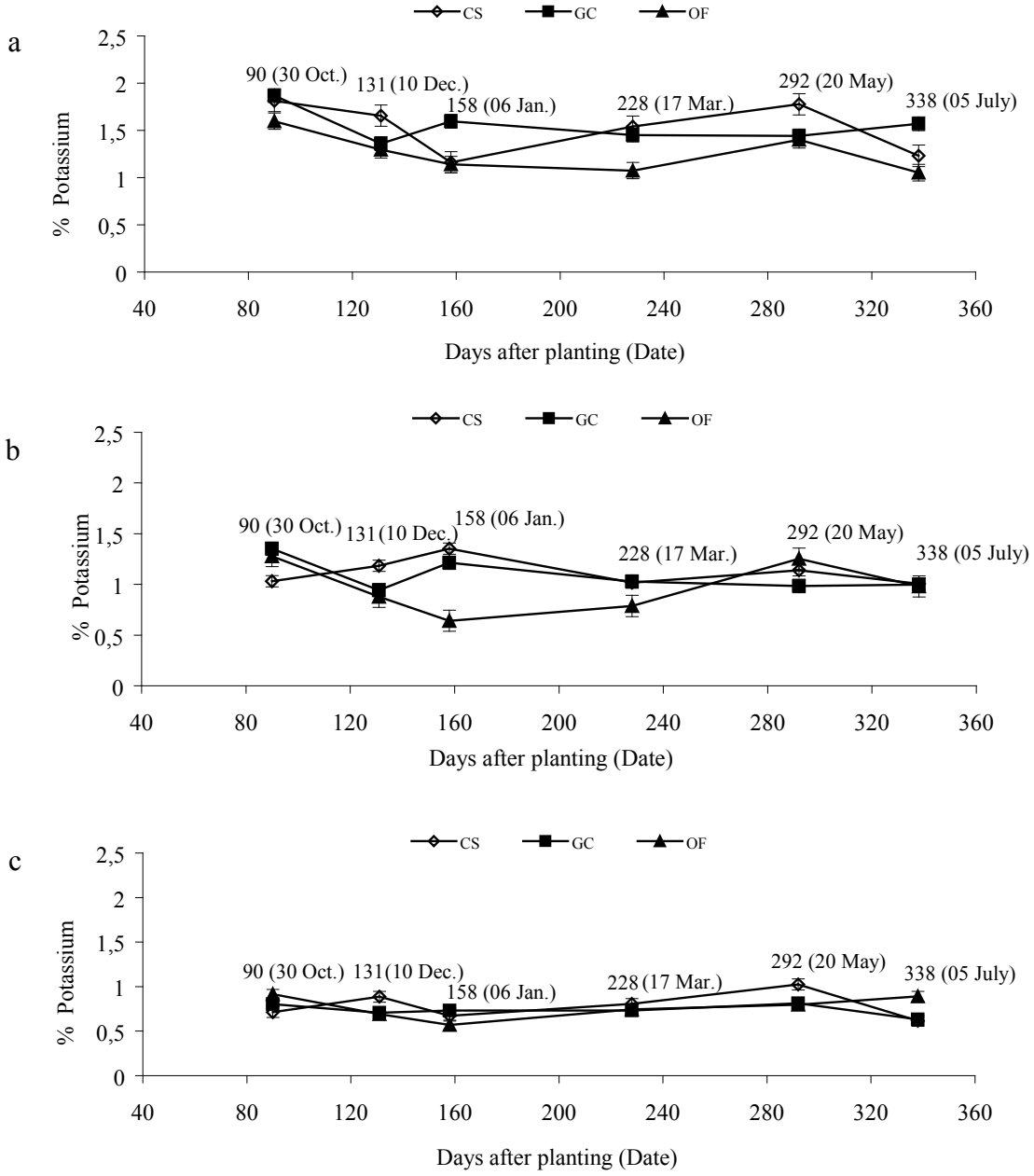


Note. Explanations under Figure 2.

Figure 3. P variation in leaf (F value: T = 14.09***, D = 17.57***, T × D = 2.54*) [a], crown (F value: T = 4.25*, D = 11.52***, T × D = 1.40 ns) [b], root (F value: T = 13.95***, D = 8.27***, T × D = 1.84 ns) [c] of 'Sweet Charlie' strawberry under different irradiation.

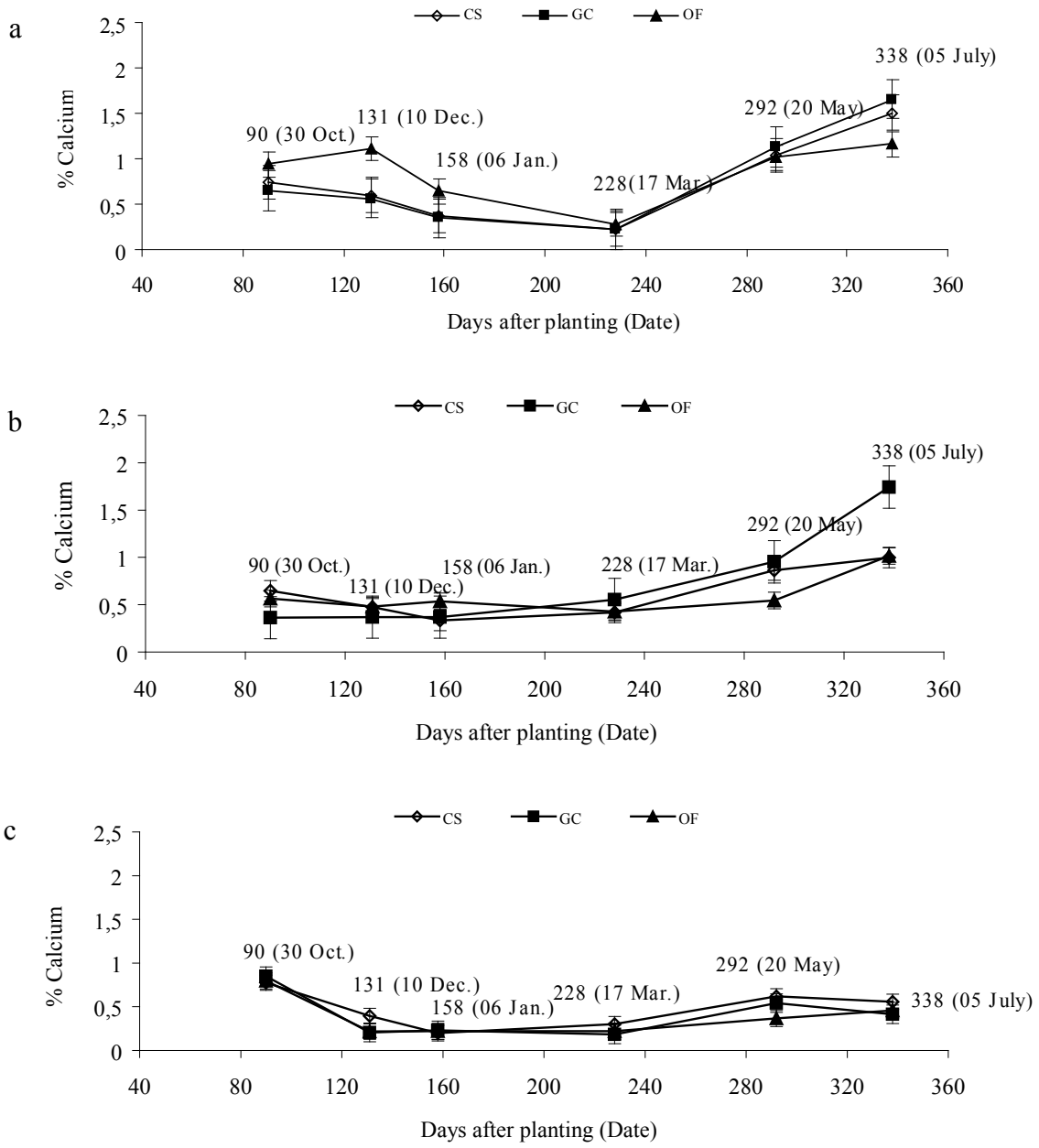
days in OF (Table 1). The increase in foliar N between these dates in OF may result from delaying of all phenology of the plants (Table 1) because of lower air and soil temperature (Fig. 1). Daugaard (2001) found a general increase in N content during spring followed by a decline at harvest. The increase during spring is explained by a gradual rise in temperature, followed by an increase in mineralization, and later the strawberry plants used the soil N reserve (Daugaard, 2001). Also, Lieten and Misotten (1993) indicated that N uptake decreased especially during green fruit stage and harvest period. Ersoy and Demirsoy (2006) reported that N in leaves during fruiting period moved from leaves to fruit. In addition, the researchers informed that the decrease in leaf could result from dilution in leaves because of increasing crown size and leaf area. N content in leaves varied from 1.29% to 2.5% during the experiment. May and Pritts (1990) explained that foliar N varied from 2.0% to 2.8% in strawberries. N content in crown increased prior to spring and decreased during flowering, fruiting and har-

vest periods. Guilin et al. (1999) found that crown N declined with development of strawberry plants. In the experiment, N content in crown varied from 1.16% to 2.54%. Ersoy and Demirsoy (2006) also reported that crown N content varied from 0.82% to 1.98% in 'Camarosa' strawberry. Also, N content in root generally increased prior to spring and then declined. N content in root during the experiment varied from 1.03% to 1.83%. Ersoy and Demirsoy (2006) determined that root N content varied from 1.13% to 2.24 % in cv. 'Camarosa'. N content in all the parts (leaf, crown, and root) decreased during harvest due to the demand of the fruits. Other studies (Albregts, Howard, 1980; Human, Kotze, 1990; Archbold, MacKown, 1995) reported that N content in different parts of the plant decreased from the beginning of fruiting period to the end of harvest. Lieten and Misotten (1993) informed that an almost equal part of N was consumed by the fruits and the other plant organs. In the experiment, N accumulated mostly in the CS and GC in greenhouse depending on development of the plants due to higher temperatures (Fig. 1).



Note. Explanations under Figure 2.

Figure 4. K variation in leaf (F value: T = 9.92***, D = 6.19***, T × D = 1.78 ns) [a], crown (F value: T = 4.87*, D = 3.95**, T × D = 5.05***) [b], root (F value: T = 0.38 ns, D = 1.69 ns, T × D = 1.29 ns) [c] of 'Sweet Charlie' strawberry under different irradiation.



Note. Explanations under Figure 2.

Figure 5. Ca variation in leaf (F value: T = 1.53 ns, D = 37.63***, T × D = 2.58*) [a], crown (F value: T = 3.33*, D = 37.20***, T × D = 5.64***) [b], root (F value: T = 2.68 ns, D = 14.08***, T × D = 0.93 ns) [c] of 'Sweet Charlie' strawberry under different irradiation

Foliar P content generally increased slightly in GC and CS treatments from the 90th through 131st day after planting (Fig. 3). After 131st day, foliar P in these treatments (except for slightly increasing in CS) began to decrease and then significantly decreased from the 228th through 292nd days including fruiting period. This case could result from the fact that P was used for flowering and fruit set as reported by Kacar (1984). It increased from the 292nd through the end of the summer growth period in GC and CS. While foliar P content in plants OF slightly decreased from the 90th through 228th day after planting, it significantly decreased from 292nd day with the beginning of harvest period (Table 1). Foliar P varied from 0.21% to 0.46% in the experiment. May and Pritts (1993) indicated that foliar P varied from 0.40% to 0.25% in strawberry. Almaliotis et al. (2002) determined that sufficiency leaf P level varied from 0.20% to 0.38% in cv. 'Tudla'. Foliar P in OF was the least in comparison with the other treat-

ments because of lower soil temperature (Fig. 1) just as May and Pritts (1990) reported that leaf P was the largest at a soil temperature of 65°F (+18°C). In the study, P content varied from 0.21% to 0.48% in crown. Ersoy and Demirsoy (2006) found that crown P varied from 0.21% to 0.35% in cv. 'Camarosa'. Ferree and Stang (1988) informed that crown P varied from 0.40% to 0.25% in cv. 'Earliglow'. Crown P in CS and GC was generally stable from planting through the 228th day, while generally decreasing from the 228th through 292nd day. Crown P content of the plants in OF increased from the 131st through 158th day after planting and decreased from the 158th day to end of the summer growth period. Root P content of 'Sweet Charlie' plants varied from 0.22% to 0.52%. Ersoy and Demirsoy (2006) reported that root P content was 0.24–0.30% in 'Camarosa'. Root P content in all treatments decreased during flowering and harvest period (Fig. 3, Table 1). John et al. (1975) reported that root P may have moved to the leaf and crown during flowering. P content in individual strawberry organs in all treatments decreased during flowering and prior to ripening. Lieten and Misotten (1993) reported that a high amount of P concentrated in the fruits at the expense of other plant organs, where P concentration decreased in this period. Leaf, crown and root P accumulation in CS and GC treatments was very close to each other because of their similar soil temperature (except autumn-winter period for root). Root P contents in CS and GC were contrary to each other in autumn-winter period. Root P content in CS increased from planting to 131st day, possibly resulting from poor plant development depending on lower light intensity (Fig. 1), and then it decreased during the experiment. The previous studies (Ferree, Stang, 1988; Chandler et al., 1992; Awang, Atherton, 1995; Fletcher et al., 2002; Ozturk, Demırsoy, 2006) revealed that shading reduced vegetative growth (leaf number, leaf area, dry weight of the plant, the leaf, the crown and the root) in strawberries.

In the experiment, K content in leaf did not show a definite harmonious tendency (Fig. 4). Leaf K content varied from 1.05% to 1.87%. Stanisavljevic et al. (1997) also reported that foliar K was 1.06%. Foliar K accumulation in CS up to January and OF up to early spring (17 March) declined while it significantly increased in both treatments from these times to the 20th of May. Foliar K in both treatments decreased from this period through the end of the experiment. K content in leaf in GC decreased from the 90th to the 131st day and increased from the 131st to 158th day. Unlike the other treatments, foliar K in GC slightly decreased during vegetative period and early fruit ripening (from 17 March to 20 May) (Fig. 3, Table 2), possibly due to much higher yield in GC in comparison to OF and CS treatments as determined by Demirsoy et al. (2007) for 'Sweet Charlie'. Foliar K content was the lowest in OF treatment because of low soil temperature (Fig. 1). Roberts and Kenworthy (1956) reported that leaf K increased as soil temperature increased. K concentration in crown in GC and CS was generally increased during winter while it generally was stable in both treatments during flowering and early fruit ripening period (from 17 March to 20 May). Crown K in OF reduced from the 90th to 158th day and increased from this period through the 20th of May. Because of lower soil temperature, K content in crown was the least in OF through the winter (Fig. 1). Crown K content decreased in all treatments by the end of harvest period. In the experiment, K content in crown varied from 0.64% to 1.35%. Stanislavljevic et al. (1997) reported that K concentration in crown was 0.45%. In the experiment, K content in root varied from 0.62% to 1.03%. Ersoy and Demirsoy (2006) reported that root K varied from 0.53% to 1.24% in 'Camarosa' strawberry. Contents of root K in CS and GC were highest during flowering and early fruit ripening period (from 17 March to 20 May) and less during harvest period. K content in all parts of plant generally increased with flowering and then decreased with ripening (Fig. 4, Table 2). Also, Lieten and Misotten (1993) reported that fruits accumulated most of the K compared to other organs.

With the exception of increasing between the 90th and 131st days in OF, which can be explained with the less plant development in OF in autumn due to reducing temperatures and photoperiod (Fig. 1) as determined by Ozturk and Demirsoy (2004; 2006) for 'Camarosa' cv., calcium content in leaves significantly decreased in all treatments from planting through March, and increased from March to end of the harvest (Fig. 5, Table 1). Also, Daugaard (2001) reported that Ca content gradually increased during summer. The increase is likely to have resulted from an increase of Ca uptake during warm periods because of increasing transpiration as informed by May and Pritts (1990). Foliar Ca varied from 0.22% to 1.50%. Almaliotis et al. (2002) reported that leaf Ca varied from 0.77% to 1.48% in 'Tudla' strawberry. Adequate foliar Ca is 0.5–1.5% in strawberry according to Cline (1991). The content of Ca in crown was almost constant from planting to vegetative growth (17 March) and generally increased with the beginning of vegetative growth. This case could result from the fact that temperature increased as reported by Ersoy and Demirsoy (2006). In the experiment, Ca content in crown varied from 0.33% to 1.74%. Stanislavljevic et al. (1997) reported that crown Ca was 1.33%. Root Ca content significantly decreased in autumn period in all treatments and did not vary markedly during winter especially in GC and OF. It increased in all treatments with increasing air and soil temperature

from early spring (17 March). Root Ca content significantly decreased toward summer in CS and GC treatments, most likely because of more move of Ca from root to leaf due to higher air temperature and transpiration in the greenhouse (Fig. 1, 5). Likewise, according to Choi et al. (1997) transpiration is the main driving force for calcium transport to various plant organs. Ca content in root varied from 0.18% to 0.85%. The data agreed with the result of Ersoy and Demirsoy (2006). The uptake of Ca was lower than those of K and N as indicated by Lieten and Misotten (1993). Most of Ca accumulated in crown and leaves. Ca uptake showed a peak at the time of flowering and during ripening because of increasing temperature and light intensity (Fig. 1, Table 2). Like us, Taiz and Zeiger (2002) found that light intensity and temperature affect transpiration, therefore, Ca uptake increased.

Conclusions

1. OF, CS and GC treatments changed nutrition contents sometimes in 'Sweet Charlie' cv. affecting plant development depending on prevailing climatic conditions. Nutrient contents of individual plant organs in OF were lower because of lower temperature than those of CS and GC.

2. N, P and K contents of the leaf, crown and root of 'Sweet Charlie' cv. were related to vegetative growth and the matters excessively used by the plant in spring; Ca content was related to transpiration with increasing temperature as parallel to known in literature.

3. In 'Sweet Charlie' cv., seasonal variation of N, P, K and Ca was as follows:

N content increased in winter and decreased during flowering and fruit ripening because of consumption during fruit production.

Phosphorus generally accumulated in autumn and winter and reduced with the beginning of the growth period.

K content generally increased with flowering and then decreased during ripening.

Ca content generally increased in spring and summer with increasing temperature.

Higher consumption of N, P and K occurred during vegetative growth and fruiting periods. This case indicated that there is a need to adjust accepted fertilization practices.

4. There was no single time at which leaves should be collected for diagnostic proposes; different standards for analyses should be developed for different growing periods.

As a result, all climatic relations such as temperature, light intensity, and rainfall having an impact on nutrient accumulation and/or mineralization in soil, as well as variety, cultivation, degree of ripeness may also affect the seasonal variation of mineral content of strawberry organs.

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N, P, K ir Ca kiekio sezoninė kaita braškių veislės 'Sweet Charlie' augalų lapuose, rageliuose ir šaknyse, esant skirtingam apšvietimui

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Santrauka

Tirta mineralinių maisto medžiagų (N, P, K bei Ca) kiekio sezoninė kaita braškių veislės 'Sweet Charlie' augalų lapuose, rageliuose ir šaknyse, esant skirtingam apšvietimui. Bandymą sudarė trys variantai: šiltnamyje (kontrolinis variantas – K), esant nuolatiniam dengimui (PD) ir atvirame lauke (AL). Lapų, ragelių ir šaknų pavyzdžiai imti įvairiais augalų augimo tarpsniais, o mineralų kiekis juose nustatytas taikant standartinį sausų pelenų metodą. Visų tirtų elementų kiekis buvo išreikštas procentais sausojoje masėje. Maisto medžiagų kiekis augalų lapuose, rageliuose ir šaknyse keitėsi priklausomai nuo bandymo varianto ir augimo tarpsnio. Buvo nustatyta, kad visuose variantuose N, P bei K kiekis sumažėjo žydėjimo ir derliaus nuėmimo metu, nes jie buvo sunaudoti uogų formavimui. Didžiausias kalcio pasisavinimas nustatytas žydėjimo ir uogų nokimo metu dėl didėjančios temperatūros. Bandymo metu atskirose augalo dalyse maisto medžiagų kiekis AL varianto buvo mažesnis nei PD ir K variantų.

Reikšminiai žodžiai: braškės, mineraliniai elementai, sezoninė kaita, apšvietimas.