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Effect of Various Development Periods on Accumulation of Some Mineral Elements on the Leaves of Strawberry Cultivars (*Fragaria* X *ananassa* Dutch. L)

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An experiment has been set up with Tudla, Muir, Douglas, Rupella, Moraline, Evita, Aiko, Northeastern, Tioga, Elvira and Delmarvel cultivars for mineral accumulations of nitrogen, phosphorus, potassium, calcium, magnesium, manganese, zinc, copper, iron and boron on plants' leaves were analyzed in three different periods which are fruit formation (May 26th), stolon formation (July 13th) and beginning of resting period (September 27th). It was determined that generally mineral elements accumulation change in relation to development periods. In addition, the periodic change in nitrogen, potassium, manganese, zinc, copper and boron minerals were more evident. No clear change was seen in phosphorus and calcium. Despite that changes were seen in iron mineral at the cultivar level, this situation did not present itself in general averages. When every cultivar is analyzed by itself, there were clear differences among cultivars. Every cultivar's mineral element accumulation level has shown variation. Differences among cultivars' averages have been found statistically significant.

Key Words: Strawberry, Development period, Mineral element, Cultivars, Leaves.

INTRODUCTION

Presence of nutritional elements in soil has an important effect on plant development. One of the most important requirements for obtaining sufficient amount of strawberry crops on a regular basis is the presence of nutritional elements and their regular intake. It needs regular irrigation and fertilization because of being a shallow-rooted, herbaceous and multi-year plant[1]. In strawberry cultivation done either for fruit or runner production, whether the plant develops healthy or not is understood by analysis of nutritional elements in leaves[2]. Yield and fruit quality's relation to nutrition and nutritional elements in leaves is known[3-5]. Therefore, synchronization can be formed among fruit or runner production and fertilization[6].

In different development phases, important physiological and biochemical changes occur in plant's various parts. Leaves are the most important organs for these changes. It was determined that during the development season, nutrition levels in leaves follow a fluctuating course[7]. Levels of most of the nutritional elements go through a fast change during periods such as flowering and fruit formation when the metabolic activity is high. However it was determined that phosphorus did not change during the season. Nitrogen has not changed after the harvest period despite that it decreased appreciably before that. However it was observed that the plant which prepares for winter increases the nitrogen level in leaves beginning in the early fall period, before winter. It was seen that magnesium and calcium are at high levels in the beginning and end of harvest period and decrease after the harvest period. It was reported that generally, the amounts of nutritional elements do not change much during the six weeks after the harvest period but start to change in the fall period[7-10].

The purpose of this study is to determine the changes of some mineral elements (N, P, K, Ca, Mg, Mn, Zn, Cu, Fe, B) in 11 different strawberry cultivars (Tudla, Muir, Douglas, Rupella, Moraline, Evita, Aiko, Northeastern, Tioga, Elvira and Delmarvel) by leaf analysis in three different periods which are fruit formation (May 26th), stolon formation (July 13th) and beginning of resting period (September 27th). Changes in mineral elements in relation to physiological developments will reveal plants' periodic mineral element requirements.

EXPERIMENTAL

The experiment has been conducted in Yüzüncü Yil University Agriculture Faculty Horticulture Department's Research and Practice areas with frigo plants that belong to Tudla, Muir, Douglas, Rupella, Moraline, Evita, Aiko, Northeastern, Tioga, Elvira and Delmarvel cultivars. Planting has occurred on July 10th, 2003. Planting has been arranged with 3 replications, 20 plants being in every replication and completely in a randomized design. After the planting, watering operation was been done by dripping method. Other maintenance works have been conducted regularly. First year, fruit and stolon formation were not allowed for ensuring healthy development. Flower cluster and stolon that formed were broken off. The next year, normal development of plants was allowed. Flower, fruit and stolon formations were not prevented.

Some soil and climate characteristics of the experiment site: The structural characteristics of the soil belonging to experiment site has been given in Table-1. The experiment region is slightly basic and poor in loamy and organic matter. The climate data belonging to experiment site has been given in Table-2. The Experiment area is located in a region where winters are snowy and cold, summers are dry and hot.

TABLE-1
STRUCTURAL CHARACTERISTICS OF THE EXPERIMENT SOIL

Texture	pH	Salt (%)	Lime (%)	Organic matter (%)	P (µg g^{-1})	K (µg g^{-1})	Saturation (%)
Clay loam	7.9	0.02	12.2	0.12	4.82	4.12	54

TABLE-2
AVERAGE CLIMATE DATA OF THE EXPERIMENT SITE FOR THE YEAR OF 2003-2004

Years (months)	Temp. means (ºC)	Max. temp. (ºC)	Min. temp. (ºC)	Total precip. (mm)	Humidity (%)	The day numbers of snow	The day numbers of frost
2003							
July	23.1	31.0	13.7	-	53.4	-	-
Agust	22.8	27.8	13.5	15.7	56.2	-	-
Sept.	17.0	28.6	7.8	16.4	64.5	-	-
Oct.	13.0	22.6	-1.0	23.6	71.0	-	1
Nov.	4.5	16.4	-4.4	59.6	74.4	2	12
Dec.	0.2	11.6	-9.8	14.9	76.7	8	24
2004							
Jan.	-0.9	7.3	-10.3	25.0	78.8	16	30
Feb	-0.6	10.2	-10.9	39.6	76.1	13	27
March	3.7	19.8	-6.4	69.9	72.3	3	19
April	6.9	20.3	-9.8	26.9	66.4	-	7
May.	12.4	22.0	2.6	68.7	67.8	-	-
June	18.5	28.7	8.5	3.1	57.8	-	-
July	21.4	30.3	9.8	2.0	52.7	-	-
Agust	22.2	29.8	10.2	-	46.5	-	-
Sept.	18.0	32.1	8.6	-	48.7	-	-
Oct.	12.0	26.8	1.2	48.1	64.1	-	-
Nov.	4.6	15.2	-8.2	102.4	75.1	8	8
Dec.	-3.7	2.4	-8.2	41.0	73.8	30	31

Analyses: The year after the plantation, leaf samples have been taken from plants in three different periods which are the fruit formation (May 26th 2004), stolon formation (July 13th 2004) and the beginning of resting periods (September 27th 2004); in order to analyze change of nitrogen, phosphorus, potassium, calcium, magnesium, manganese, zinc, copper, iron, boron minerals. Leaf samples were collected[11], among those which had completed their development recently and 40 pieces from each plot. After the leaf samples have been collected, they were dried at 65ºC for 48 h and then grinded. In these samples, analysis was done using nitrogen by Kjeldahl method, phosphorus by spectrophotometer, potassium, calcium, magnesium flame photometer and iron, manganese, zinc, copper and boron by atomic absorption spectrophotometer[12].

RESULTS AND DISCUSSION

The amount of nitrogen has rise in measurements in the beginning of the resting period in all cultivars (Table-3). This value has surprisingly reached 4.97 % in Muir cultivar. While a regular increase is observed in Tudla, Muir and Delmarvel cultivars, there was some decrease in Douglas, Rupella, Moraline, Evita, Aiko, Northeastern, Tioga and Elvira cultivars in July 13. However nitrogen accumulation has increased in September 27 and a clear rise has appeared. In these cultivars, the decreases in averages of July 13 were not much compared the averages of May 26. The averages of May 26 and July 13 were in the same group statistically according to the average values given with respect to sampling times in Table-5. The general average of May 26 was 1.89 % and July 13 was 1.90 %. In addition to this, the nitrogen average has increased to 2.39 % in September 27 with a clear rise. According to Table-4, nitrogen accumulation averages in plants have shown variation with respect to cultivars. The differences among the cultivar averages have been found statistically significant.

The averages of phosphorus amounts show variation with respect to the sampling time in all cultivars (Table-3). Despite that the differences among the averages are considered statistically significant, it should be noted that these differences are small. In Tudla, Muir, Douglas, Rupella, Evita, Aiko, Tioga and Delmarvel cultivars, there is a slight decrease in July 13 values compared to May 26 values, however there is a slight increase again in September 27 values. In Moraline, Northeastern and Elvira cultivars, a rise in July 13 and a fall in September 27 has appeared. Despite that the differences among the general cultivar averages (Table-4) are small, they have been found statistically significant. When the general averages given with respect to sampling times are analyzed (Table-5), it is seen that the phosphorus amount does not show a serious amount of variation in relation to the periods. However, despite the small differences, July 13 averages are placed in a different statistical group from the general averages obtained on dates of May 26th and September 27th.

Potassium amount shows variation with respect to the sampling times in all cultivars (Table-3). The differences among average values have been found statistically significant. In Tudla, Douglas, Rupella, Moraline and

Aiko cultivars, a decrease in July 13 values and then increase in September 27 values have been observed compared to May 26 values. In Muir, Evita, Northeastern, Tioga and Elvira cultivars, a continuous decrease has been observed with respect to sampling times. In Delmarvel cultivar, compared to the May 26 average, potassium amount has increased in the July 13 average and then decreased in the September 27 average. Cultivar averages of potassium amount (Table-4) have been found different and the differences among the cultivars have been considered statistically significant. When Table-5 is analyzed, it has been observed that the potassium contents generally decreases depending on time. However it should be remembered that general average values vary with respect to cultivars.

Calcium amount vary with respect to the cultivars and its accumulation increased in the resting period (Table-3). In Tudla, Douglas and Tioga cultivars, average calcium amount has increased regularly at sampling times. However in Rupella, Moraline, Aiko and Delmarvel cultivars, July 13 averages were lower than May 26 averages and then in September 27 the average values increased again. In Evita, Northeastern and Elvira cultivars, just the opposite is true. July 13 averages are higher than the May 26 and September 27 values. The most surprising cultivar is the Muir cultivar. May 26 average of the Muir cultivar was 1.03 %. When the general averages of all cultivars are considered (Table-4), it will be seen that the differences among cultivars are not much. However the differences among cultivar averages have been found statistically significant. When the general averages of sampling times are analyzed (Table-5), it was determined that the differences among the averages are small. The differences among averages have not been found statistically significant.

Despite of the differences among magnesium averages remained at low levels, differences among the averages of sampling times within the cultivar (Table-4) and among cultivars (Table-5) have been found statistically significant. However in general evaluations done by sampling times (Table-5), the differences among the averages were found statistically insignificant. May 26 average was 0.13 % and July 13 and September 27 averages were 0.12 %. In average values obtained with respect to sampling times within a cultivar (Table-3), generally July 13 averages have decreased compared to May 26 averages and increased again in September 27. It can be said that before plants enter the fall resting period, they accumulate magnesium. However this situation has not happened at the same level in all cultivars. Tioga cultivar, as opposed to the general situation, has a higher July 13 average (0.29 %) than May 26 (0.14 %) and September 27 (0.08 %) averages. In Elvira and Tioga cultivars, there was a general decrease in September 27. Although the results vary in relation to the cultivar, the strawberry plant makes magnesium accumulation in the fall period.

The differences among manganese averages with respect to application times within cultivars (Table-3) are found statistically significant. In Tudla, Douglas, Aiko, Northeastern and Delmarvel cultivars, it was determined that manganese accumulation decreased as the development period progressed. However in Muir, Rupella, Moraline, Evita, Tioga and Elvira cultivars, manganese accumulation on leaves decreased in stolon formation period (July 13), but increased again when entering the fall period (September 27). The amount of this increase varies depending on the cultivar. When periodic manganese accumulations with respect to sampling times (Table-5) are analyzed, it is observed that plants enter the fall period start to accumulate manganese. Also, the differences among the averages are found statistically significant. When the cultivar averages in Table-4 were analyzed, it was determined that manganese accumulation in leaves varied with respect to the cultivar and the difference among the averages were statistically significant. Cultivar averages varied between 8.27 and 21.50 µg g^{-1}.

When the zinc accumulation averages on leaves given in Table-3 with respect to sampling times within a cultivar are analyzed, it is seen that Tudla, Muir, Douglas, Rupella, Moraline, Aiko and Delmarvel cultivars' values decrease in the middle of the growth season (July 13) and increase at the end of the growth season (September 27). In Evita, Northeastern, Tioga and Elvira cultivars, no increase was determined on September 27th. The reason of this may be that plants had not made any preparations for the resting period yet. However it can also be concluded that these cultivars do not make zinc accumulations as a result of their own characteristics. An accurate result can be reached by doing analyses on the subjects after September 27 for a few more periods with certain intervals. When general averages related to zinc's accumulation values on leaves (Table-5) are analyzed, the average falls from 16.98 µg g^{-1} in May 26 to 13.37 µg g^{-1} and in September 27 it rises again to 14.55 µg g^{-1}. It was determined that zinc accumulation amounts vary with respect to cultivars and the obtained general averages are statistically significant (Table-4).

Like other mineral elements, copper accumulations on leaves also showed periodic variation. When the averages in Table-3 with respect to sampling times within a cultivar are analyzed, copper accumulations of Muir, Douglas, Rupella, Northeastern cultivars have decreased in July 13 and then started increasing. It has been observed that copper accumulation is still at a low level in the beginning of the resting period. This situation holds for Tudla, Moraline, Evita, Aiko, Tioga, Elvira and Delmarvel cultivars. Moreover, the decrease is continuous in Evita and Elvira cultivars. When general averages of sampling times are analyzed (Table-5), the periodic fall in averages is seen well. Despite that the September 27 average (8,43 µg g^{-1}) has a tendency to rise, it still has not reached May 26 average value (10.19 µg g^{-1}). When copper accumulation averages of cultivars (Table-4) are analyzed, the differences among cultivar averages were determined statistically significant.

Variations in cultivars' periodic iron accumulations are given in Table-3. Periodic changes of iron accumulations in plants vary with respect to cultivars. In Douglas, Northeastern and Elvira cultivars, July 13 averages are higher than May 26 and September 27 averages. This means that the low value in the beginning of the growth season has increased in the middle and then decreased again at the end. The highest average value is reached at the fall period. In Tudla, Muir and Evita cultivars, stolon formation period (July 13) value has dropped compared to the fruit formation period (May 26) and then rise again in the fall period (September 17). In Moraline and Aiko cultivars, iron content in leaves drop continuously throughout the growth season. Obviously, the periodic change of iron content of strawberry cultivars varies. When the cultivar averages in Table-4 are analyzed, the differences among the cultivars have been found statistically significant. Cultivar averages have a distribution from 142.39 to 202.97 µg g^{-1}. In general evaluation done with respect to sampling times (Table-5), it is seen that iron accumulation on leaves increase some amount in stolon forming period but then decrease again. The small differences among the averages were not found statistically significant.

Accumulation of boron element on leaves have dropped in July 13 samples compared to May 26 samples and increased again in the beginning of the resting period (September 27) in all cultivars except for Tioga. In Tioga cultivar, accumulation value of boron element on leaves which was 34.13 µg g^{-1} on May 26th has reached 34.42 µg g^{-1} on July 13th and then by continuing to increase reached 39.04 µg g^{-1} on September 27th. The fluctuating course of boron mineral will be seen well with general averages of sampling times. The value has decreased from 33.89 µg g^{-1} in May 26 to 25.92 µg g^{-1} in July 13. However this value has increased again and reached 38.18 µg g^{-1} in September 27. When cultivar averages (Table-4) are analyzed, the big differences among the averages will be seen. The differences among the averages were found statistically significant.

Like other species, mineral element requirements of strawberry plants will also increase in physiological periods such as flower bud formation, flowering, fruit formation and stolon formation. However, significance level of mineral elements can change in different periods. Results obtained by leaf analysis are helpful in this matter[13,14].

Average values obtained from nitrogen mineral are in agreement with previous studies[7,8,11]. In Monard and Lacroix-Raynal's study[9], nitrogen levels were high. In results of these researchers, there were no serious changes in nitrogen averages in the beginning of flowering (3.7 %), beginning of fruit maturity (3.5 %) and full crop periods (3.5 %). When analyzed at the cultivar level, it was seen that some cultivars' (Douglas, Rupella, Moraline, Aiko and Elvira) nitrogen levels had dropped in July 13 period. According to Tworkoski *et al.*[2], the reason of this can be explained by plants' need for nitrogen in stolon formation period. Other cultivars might have prevented the change of nitrogen level in leaves by taking nitrogen from soil inten sively. The reason of this may be sourced in richness of soil's nutritional content as well as cultivar differences.

In present study, general phosphorus accumulation averages (Table-5) were obtained as 0.42 % in May 26, 0.40 % in July 13 and 0.43 % in September 27. Bould[8] obtained phosphorus accumulation in leaves as 0.37 % in flowering period, 0.28 % in fruit formation period and 0.19 % in the period after harvest. The values obtained by Bould[8] seems to be lower than the values in present studies. However, when compare the present values with Monard and Lacroix-Raynall's[9] 0.83 % in the beginning of the flowering period, 0.73 % in early fruit maturity period and 0.43 % in full crop period, present values are lower. The reason of this must have stemmed from the cultivar differences. Bould[8] has used the Climax cultivar and Lacroix-Raynal[9] has used the Gariuetta cultivar. The present values include 11 different cultivars. Choi *et al.*[15] has determined that humidity which is one of the environmental factors also increases mineral element absorption. Low humidity (Table-2) in the experiment area can be an important factor.

Potassium amount changes in relation to the cultivar and periods and varied between 0.32 and 0.83 %. Although these values are close to Stonisavlijevic *et al.*[10] report, who have conducted and the periodic variations (0.93 % lowest, 1.26 % highest) were determined, present values are still lower. In present study, potassium amount continuously dropped during the development period. In the study Bould[8] had conducted with the Climax cultivar, a continuous decrease has been observed. Results of John *et al.*[7] and Stonisauljevic *et al.*[10] also quite similar. As the development period progressed, potassium amount continuously dropped. In all the studies mentioned above, potassium amounts were higher than the values of present studies.

The similarity of the periodic changes of calcium and magnesium accumulations is in line with other studies[7,10,11]. There were not remarkable changes in calcium and magnesium amounts during the development period. However, in some studies[8,9], presence of calcium accumulation was observed when entering the resting period in fall. However, this level of increase was low. No appreciable changes were observed.

TABLE-3
AVERAGE VALUES OF MINERAL ELEMENT ACCUMULATIONS ON LEAVES OF TUDLA, MUIR, DOUGLAS, RUPELLA, MORALINE, EVITA, AIKO, NORTHEASTERN, TIOGA, ELVIRA AND DELMARVEL CULTIVARS WITH RESPECT TO SAMPLING TIMES

Cultivars	Sampling time	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Mn (µg g^{1})	Zn (µg g^{1})	Cu (µg g^{1})	Fe (µg g^{1})	B (µg g^{1})
Tudla	26 May	1.74c*	0.45a	0.47a	0.31c	0.12a	14.51a	18.12a	11.58a	185.13b	24.05b
	13 July	1.87b	0.41b	0.33c	0.34b	0.08b	10.13b	10.36c	7.10b	169.67c	11.76c
	27 Sep	1.98a	0.45a	0.41b	0.38a	0.09b	8.46c	12.34b	7.22b	254.10a	28.40a
Muir	26 May	1.59b	0.45a	0.83a	1.03a	0.12a	8.85b	12.98b	9.95a	187.15a	27.52b
	13 July	1.85b	0.33c	0.36b	0.54b	0.09b	7.48c	12.80b	6.75b	143.68c	24.12b
	27 Sep	4.97a	0.40b	0.35b	0.42b	0.12a	14.31a	13.59a	9.21a	161.36b	46.71a
Douglas	26 May	2.03a	0.38a	0.53a	0.39b	0.14a	12.89b	20.14a	11.63a	129.66c	24.68b
	13 July	1.94b	0.34b	0.37c	0.37b	0.08b	14.94a	14.12b	8.84b	207.79a	24.47b
	27 Sep	2.13a	0.40a	0.41b	0.57a	0.14a	7.13c	19.10a	10.48b	195.80b	35.51a
Rupella	26 May	1.90b	0.45a	0.53a	0.45b	0.16a	18.12b	15.33a	10.47b	168.42c	41.76a
	13 July	1.85b	0.41b	0.37c	0.39c	0.10b	18.74b	14.73b	8.80c	174.00b	20.66b
	27 Sep	2.10a	0.46a	0.44b	0.52a	0.18a	20.02a	15.80a	13.81a	188.12a	42.65a
Moraline	26 May	1.85a	0.41b	0.54a	0.53a	0.18a	24.72a	19.51a	8.70a	225.60a	39.68a
	13 July	1.68b	0.45a	0.34c	0.41c	0.11b	17.80c	12.56b	7.01b	175.47b	23.82c
	27 Sep	1.94a	0.43a	0.45b	0.47b	0.17a	21.99b	16.93a	7.96b	126.90c	33.10b
Evita	26 May	1.84b	0.49a	0.50a	0.33b	0.13a	13.54b	20.80a	10.75a	179.60a	41.69a
	13 July	1.81b	0.45b	0.36b	0.39a	0.10b	13.29b	15.77b	9.15b	156.24c	28.51b
	27 Sept	2.12a	0.49a	0.18c	0.32b	0.13a	28.66a	15.90b	4.78c	182.10a	41.16a
Aiko	26 May	1.78a	0.45a	0.53a	0.65a	0.17a	11.23a	11.87a	9.83a	169.08a	32.14b
	13 July	1.57c	0.42a	0.32b	0.33c	0.08c	9.47b	9.78b	7.23b	131.20b	29.29c
	27 Sept	1.69b	0.39b	0.35b	0.42b	0.14b	5.51c	11.64a	7.92b	129.14b	39.76a
Northeastern	26 May	1.94c	0.34a	0.51a	0.33b	0.12a	19.17a	15.53a	10.20a	172.31b	31.65b
	13 July	2.12b	0.36a	0.47a	0.46a	0.13a	16.90b	11.66b	7.93c	243.01a	20.05c
	27 Sept	2.32a	0.38a	0.42b	0.36b	0.13a	15.28c	11.84b	8.52b	122.74c	35.89a

Cultivars	Sampling time	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Mn (µg g^{-1})	Zn (µg g^{-1})	Cu (µg g^{-1})	Fe (µg g^{-1})	B (µg g^{-1})
Tiago	26 May	1.93c	0.39b	0.44a	0.33b	0.14b	13.42a	8.64c	13.52a	142.05b	34.13b
	13 July	2.20b	0.37b	0.34b	0.43a	0.29a	8.59b	13.21a	8.28b	144.37b	34.42b
	27 Sept	2.35a	0.44a	0.27c	0.45a	0.08c	9.25b	11.88b	8.76b	156.57a	39.04a
Elvira	26 May	2.28b	0.41b	0.49a	0.37b	0.14a	11.75a	17.56a	8.54a	133.42c	41.56a
	13 July	1.89c	0.46a	0.32b	0.51a	0.13a	7.04b	14.23b	8.80a	177.00a	34.84c
	27 Sept	2.33a	0.43a	0.29a	0.28c	0.08b	11.44a	11.48c	7.00b	140.34b	38.77b
Delmarvel	26 May	1.87c	0.45a	0.37a	0.39a	0.12a	9.05a	26.29a	6.97c	129.36b	33.92b
	13 July	2.12b	0.39b	0.45a	0.35b	0.09b	9.36a	17.89b	8.43a	138.07b	33.16b
	27 Sept	2.33a	0.43a	0.29b	0.41a	0.09b	6.41b	19.57b	7.08b	159.74a	38.98a

*Means followed by the same letter within cultivars and column are not significantly different at ($p < 0.05$). Duncan's multiple range test.

TABLE-4
GENERAL AVERAGES OF MINERAL ELEMENT ACCUMULATIONS ON LEAVES OF TUDLA, MUIR, DOUGLAS, RUPELLA, MORALINE, EVITA, AIKO, NORTHEASTERN, TIOGA, ELVIRA AND DELMARVEL CULTIVARS

Cultivars	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Mn (µg g^{-1})	Zn (µg g^{-1})	Cu (µg g^{-1})	Fe (µg g^{-1})	B (µg g^{-1})
Tudla	1.87ef*	0.43b	0.40bc	0.34b	0.10b	11.03de	13.61fg	8.64cd	202.97a	21.40f
Muir	2.80a	0.39de	0.51a	0.67a	0.12ab	10.27ef	13.12g	8.64cd	164.06c	32.78cd
Douglas	2.04cd	0.37ef	0.44abc	0.45ab	0.12ab	11.65d	17.78b	10.32b	177.75b	28.22e
Rupella	1.95de	0.44b	0.45abc	0.45ab	0.14ab	18.96b	15.29de	11.03a	176.85b	35.02cd
Moraline	1.82f	0.43b	0.44abc	0.47ab	0.15ab	21.50a	16.33cd	7.89de	175.99b	32.20d
Evita	1.93e	0.48a	0.35c	0.35b	0.12ab	18.50b	17.49bc	8.22cd	172.65b	37.12ab
Aiko	1.68g	0.42bc	0.40bc	0.47ab	0.13ab	8.73g	11.10h	8.33cd	143.14d	33.73cd
Northeastern	2.13bc	0.36f	0.47ab	0.38b	0.12ab	17.11c	13.01g	8.88c	179.35b	29.20e
Tioga	2.16b	0.40cd	0.35c	0.40b	0.17a	10.42ef	11.24h	10.18b	147.66d	35.86abc
Elvira	2.17b	0.43b	0.37c	0.38b	0.11ab	10.08f	14.42ef	8.12de	150.25d	38.39a
Delmarvel	2.11bc	0.42b	0.37c	0.38b	0.10b	8.27g	21.25a	7.50e	142.39d	35.35abcd

*Means followed by the same letter within cultivars and column are not significantly different at ($p < 0.05$). Duncan's multiple range test.

TABLE-5
GENERAL AVERAGES OF MINERAL ELEMENT ACCUMULATION ON MAY 26th, July 13th AND SEPTEMBER 27th

Sampling time	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Mn (µg g^{-1})	Zn (µg g^{-1})	Cu (µg g^{-1})	Fe (µg g^{-1})	B (µg g^{-1})
26 May	1.89b*	0.42a	0.52a	0.46a	0.13a	14.30a	16.98a	10.19a	165.62a	33.89b
13 July	1.90b	0.40b	0.37b	0.41a	0.12a	12.16c	13.37c	8.03c	169.14a	25.92c
27 Sept	2.39a	0.43a	0.35b	0.42a	0.12a	13.50b	14.55b	8.43b	165.17a	38.18a

*Means followed by the same letter within cultivars and column are not significantly different at ($p < 0.05$). Duncan's multiple range test.

The periodic changes of manganese, zinc, copper and boron minerals can be explained by increase and decrease of requirements in relation to physiological development periods[4]. Despite of the determination of iron mineral's periodic variation on cultivar basis (Table-3), in general periodic averages (Table-5), there seems to be no periodic changes. It is assumed that the evaluation done in cultivar level is more significant. The statement of Erdal *et al.*[16] which point out that iron accumulation shows variation in the beginning, middle and end of flowering period, shows that not only physiological periods but development process within a period can also effect the accumulation on leaves.

Conclusion

Accumulation of mineral elements can increase and decrease in relation to requirements that occur. Periodic fluctuation appears clearly particularly in nitrogen, potassium, manganese, zinc, copper and boron minerals. While there were no fluctuations observed in phosphorus amount in general, slight change was observed in some cultivars. However, when every cultivar is considered one by one periodically, different responses can be elicited. Periodic change of a mineral element in one cultivar can occur at different levels in another cultivar.

REFERENCES

1. G. Hochmuth and E. Albregts, Fertilization of Strawberries in Florida, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, Circular, p. 1141 (1984).
2. J.T. Tworkoski, T.E. Benassi and F. Takeda, *Sci. Hort.*, **88**, 97 (2001).
3. J.F. Hancock, Strawberries, CABI Publishing, New York, USA (1999).
4. R. Nestby, F. Lieten, D. Pivot, C.R. Lacroix, M. Tagliavini and B. Evenhuis, *Acta Hort.*, **649**, 201 (2004).

5. M.M. Geoffrey and M.P. Prits, *J. Am. Soc. Hort. Sci.*, **118**, 43 (1993).
6. M. Tagliavini, E. Baldi, R. Nestby, C. Raynal-Lacroix, P. Lieten, T. Solo, D. Pivot, P. L. Lucchi, G. Baruzzi and W. Faedi, *Acta Hort.*, **649**, 197 (2004).
7. M.K. John, F.D. Daubeny and F.D. McElroy, *J. Am. Soc. Hort. Sci.*, **100**, 513 (1975).
8. C. Bould, *Advances Hort. Sci.*, **1**, 173 (1961).
9. P. Monard. C. Lacroix-Raynal, *Soilless Culture*, **5**, 32 (1989).
10. M.J. Stanisavljevic, O. Gavrilovic-Damjanovic, O. Mitrovic and V. Mitrovic, *Acta Hort.*, **439**, 705 (1997).
11. S.S. Kwong and O. Boynton, *Proc. Am. Soc. Hort. Sci.*, **73**, 168 (1959).
12. M.L. Jackson, Soil Chemical Analysis, Prentice Hall, Englewood Clifts, NJ (1967).
13. R. Niskanen and R. Dris, *Acta Hort.*, **567**, 439 (2002).
14. M. Tagliavini, E. Baldi, P. Lucchi, M. Antonelli, G. Sorrenti, G. Baruzzi and W. Faedi, *Eur. J. Agron.*, **23**, 15 (2005).
15. J.H. Choi, G.C. Chung and S.R. Suh, *Sci. Hort.*, **70**, 293 (1997).
16. I. Erdal, K. Kepenek and I. Kizilgöz, *Turk J. Agric. For.*, **28**, 432 (2004).

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