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ORIGINAL PAPER

SEASONAL VARIATIONS IN LEAF NUTRIENT CONCENTRATIONS IN THREE FIG (*FICUS CARICA* L.) VARIETIES

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Abstract

Leaves from three fig (*Ficus carica* L.) varieties (White, Black Royal and White Royal) were collected at different development stages of the tree, i.e. flowering, fruit development, fruit maturity, and postharvest, after which the variation of macro- (K, Na, Ca, Mg, N, P) and micronutrient (Fe, Mn, Cu, Zn, B) concentrations during the growing season were measured. The leaf concentrations of N, P, K, Ca and Mg during the studied period for the White variety ranged from 19 to 25, from 1.1 to 1.3, from 13 to 18, from 20 to 24 and from 2.7 to 2.9 g kg^{-1} (on dry weight basis DW), respectively. The corresponding values for the Black Royal variety ranged from 22 to 26, from 1.1 to 1.4, from 13 to 19, from 23 to 29 and from 2.5 to 3.4 g kg^{-1} (DW), respectively. The corresponding values for the White Royal variety ranged from 19 to 25, 0.9 to 1.2, 10 to 17, 26 to 30 and 4.3 to 4.5 g kg^{-1} (DW), respectively. The leaf content values of Fe, Zn, Cu, Mn, and B during the studied period for the White variety ranged from 107 to 147, from 42 to 35, from 10 to 9, from 52 to 61 and from 23 to 40 mg kg^{-1} (DW), respectively. The corresponding values for the Black Royal variety ranged from 77 to 155, from 38 to 41, from 8 to 9, from 52 to 66 and from 23 to 56 mg kg^{-1} (DW), respectively. The corresponding values for the White Royal variety ranged from 84 to 126, from 44 to 48, from 8 to 9, from 88 to 98 and from 23 to 47 mg kg^{-1} (DW), respectively. According to the results, the leaf nutritional content varies in the plant's development stages and there were differences between the fig varieties in the nutrient content at different development stages, which indicated that different varieties of plants need different amounts of nutrients during the growing cycle. These results should be taken into consideration when elaborating a fertilization program.

Keywords: plant nutrition, macronutrients, micronutrients, Mediterranean climate, nutritional stages.

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INTRODUCTION

The fig tree (*Ficus carica* L.) is native to Iran, Asia Minor and Syria, and nowadays it is cultivated in warm and temperate climates. The fig tree can be grown on dry, sandy, graveled and stony soils provided they are well drained; the species shows tolerance to conditions of a shortage of water and is tolerant to moderate salinity. However, it develops better on deep loam or clay loam soils that are satisfactorily drained and have a pH from 6 to 8. In general, fig trees need light fertilization. The actual demand for fertilizers depends on the soil type, organic substance, pH, the vigour and yield of each tree, the size, age, variety, and the conditions that prevail in the region and the demand for nutrients (Therios, Dimassi-Theriou 2013). In Greece, there are many high-yielding commercial fig orchards and fig crop constitutes a significant exported product in the country's agro-economy. Nutrient concentrations in a given plant tissue are the results of uptake, vitality, transport and movement of nutrients within the plant. Climatic factors affect all these processes and may explain some of the differences in nutrient concentrations occurring in the same tissue over different time periods. Climate differences also affect the concentration of nutrients due to an effect on the degree of fruit yielding and vitality of the crop. The macro- and micronutrient content of both the leaves and other plant tissues varies depending on the age of the leaf and the time of sampling (Stylianidis et al. 2002). Optimal nutrition of fruit plants is a key factor for the growth and development of plants. Leaf mineral analysis is the best diagnostic tool for determining the nutritional status of plants and represents an efficient guide for fertilization (Chatzissavvidis et al. 2005). The position of leaf and the time of sampling are quite essential in an assessment of the nutritional status of fruit trees. Plant analysis is a very practical approach for diagnosing nutritional disorders and formulating fertilizer recommendations. In order to be able to use effectively the nutrient concentration in leaves for diagnostic purposes as well as in fertilization practice, it is necessary to know its variation concerning different nutrients throughout the growing season. Deciduous crops show seasonal changes in the mineral composition of leaves, which can have important implications for the diagnosis of nutrient disorders, post-harvest storage of the fruit and schedule of fertilizer applications (Smith et al. 1987). Nutrient accumulation curves of fruit trees are a good indicator of plants' nutrient demand at any developmental stage. They are also a useful tool for the evaluation of an orchard's nutritional status and for estimating amounts of soil nutrients removed from the substrate (Nachtigall, Dechen 2006). The aim of this work has been to evaluate the seasonal variation in macro- and micronutrient concentrations in the leaves of three fig varieties throughout a growing season under the Mediterranean climatic conditions.

MATERIALS AND METHODS

Experimental site

The studied area is located on the island Evoia, in the province of Kimi, in Greece (38°38′08.1' N, 24°03′56.4' E), and it has all the characteristics of the Mediterranean climate, with hot dry summers and mild wet winters. The average annual temperature of the region is 16.8°C. The hottest month of the year is August, with a mean atmospheric temp. of 27.6°C. January is the coldest month, with an average temp. of 5.4°C. The mean annual rainfall is 1031 mm. The highest rainfall occurs in December with an average of 153.7 mm, while the driest month is August with an average of 18.5 mm. The dry period lasts approximately for five months (May-Sept).

Plant sampling and analytical methods

Three not irrigated fig orchards (>20 years old) cultivated with different fig varieties i.e. White, Black Royal and White Royal, were selected to study the leaf variation of macro- and micronutrient concentrations during the growing cycle. The orchard cultivated with the White variety occupied an area of about 4,000 m^2 and consisted of 40 mature trees. The orchard cultivated with the White Royal variety occupied an area of about 3,000 m^2 and consisted of 30 mature trees. The orchard cultivated with the Black Royal variety occupied an area of about 3,000 m^2 and consisted of 30 mature trees. The trees in all the orchards grew in a 10 m intra-row and 8.5 m inter-row spacing arrangement. The mean yield of marketable figs in the last ten years was approximately 40 kg $tree^{-1}$ $year^{-1}$ for all the varieties.

Five uniform, healthy, mature trees were selected in each orchard for sampling during the growing season of 2018. As suggested by Beutel et al. (1983) in tests for optimum leaf nutrient concentrations in deciduous plants, fifty youngest, fully expanded, exposed leaves on non-fruiting branches were collected around the perimeter of each tree at a 1.8 m height, providing 5 replications of leaf samples for each orchard. Leaf samples were collected in late May, middle July, middle August, and late October (2018); these times corresponded to the flowering, fruit development, fruit maturity and postharvest development stages, respectively. Extremely vigorous or weak shoots were avoided at all samplings. Leaves were stored in paper bags and transferred to the laboratory, washed with deionized water, dried at 55°C for 48 h, ground in a stainless-steel Wiley mill, passed through a 150 µm plastic sieve and stored. In the <150 µm fraction of leaves, the total nitrogen was determined by the Kjeldahl method. Also, for determination of the other elements, 0.5 g of the ground leaf material was dry-ashed at 550°C for 3.5 h. Then, the ash was dissolved in 3 ml with 6 N HCl and diluted to 50 ml. In the clear solution, the concentrations of Mg, Fe, Mn, and Zn were determined by flame atomic absorption spectrophotometry, using an air-acetylene flame, while the Ca concentration was determined using an acetylene-N_2O

flame. Potassium was measured using flame photometry. Total phosphorus and boron were determined using the Murphy and Riley method and azomethine-H method, respectively. All management practices (fertilization, pesticide application) followed the standards in Greek fig orchards.

Soil sampling and analytical methods

Soil samples were taken in late October of 2017 as follows: three samples of soil were taken from depths of 0-30 and 30-60 cm equidistant around the circumference of a circle measuring 0.5 m in diameter from the trunk of each selected tree (i.e. five trees per orchard). Then, the three samples from each depth were combined and mixed separately, resulting in 5 mixed soil samples from the depth of 0-30 cm and 5 from the depth of 30-60 cm, for each orchard. Samples were dried, ground and passed through a 2 mm plastic sieve to be stored until analysis. The following soil properties were determined in the <2 mm soil fraction: soil texture using the hydrometer method; organic matter using a modified Walkley-Black method; $CaCO_3$ equivalent using the quantity of CO_2 produced in reaction with HCl; cation exchange capacity (CEC) and exchangeable bases using the NH_4OAc (1 N, pH 7) method; pH was determined in a soil:water (1:1) suspension; total nitrogen was determined using the Kjeldahl procedure; total P was assayed according to the Olsen's method; micronutrients Fe, Mn, Zn were determined with the DTPA method; and the azomethine–H method was applied to determine B. The methods of leaf and soil analyses used are described in Klute (1986) and Page et al. (1982).

Analysis of variance, including the plotting of graphs, was performed in Statistica (2008). Experimental factors were the leaf content of macro- and micronutrients in different fig varieties during the growing cycle.

RESULTS AND DISCUSSION

Soil analysis

The results of soil analysis for the three orchards are shown in Table 1. The texture in all soils and depths studied was of clay. The pH values were slightly alkaline. Equivalent calcium carbonate content was above 33%, which characterizes marl soils. The organic matter content was moderate. CEC was higher than 21.5 cmol(+)kg^{-1} of soil, which means that these soils were fertile. The levels of soil N and P were marginal. Potassium was low. The calcium concentration was high, at 31.7 cmol(+)kg^{-1} of soil, because of the method used to extract Ca from $CaCO_3$. Magnesium was at a medium level of 1.5 cmol(+)kg^{-1} of soil. Levels of micronutrients (Fe, Zn, Cu, Mn, B) ranged within the threshold limits of deficiency. The evaluation of the soil nutrient status was based on Landon (1991).

Table 1

Physical and chemical properties of the studied soils

Specification	Fig Orchards					
	White		Black Royal		White Royal	
Depth (cm)	0-30	30-60	0-30	30-60	0-30	30-60
Texture	clay	silty clay	clay	clay	clay	clay
pH	7.4	7.6	7.4	7.5	7.4	7.5
Eq. $CaCO_3$ (g kg^{-1})	340	578	562	529	400	335
Org. matter (g kg^{-1})	44	18	36	29	47	36
Total N (g kg^{-1})	2	1	2	2	2	2
P-Olsen (mg kg^{-1})	15.0	10.0	15.0	9.0	16.0	9.5
Exch. Ca (cmol(+)kg^{-1})	24.6	30.7	31.7	23.3	26	28.6
Exch. Mg (cmol(+)kg^{-1})	1.9	1.2	1.2	1.1	2.0	1.6
Exch. K (cmol(+)kg^{-1})	0.6	0.3	0.4	0.3	0.5	0.4
Exch. Na (cmol(+)kg^{-1})	0.3	0.2	0.2	0.2	0.3	0.3
CEC* (cmol(+)kg^{-1})	35.7	21.5	23.8	26.7	33.8	33.4
$Fe_{(DTPA)}$ (mg kg^{-1})	31.8	22.7	27.6	28.3	34.5	31.7
$Zn_{(DTPA)}$ (mg kg^{-1})	9.3	2.0	2.2	1.3	3.5	1.9
$Cu_{(DTPA)}$ (mg kg^{-1})	4.3	2.8	3.4	4.4	5.5	5.0
$Mn_{(DTPA)}$ (mg kg^{-1})	50.5	26.6	40.5	33.5	52.4	45.9
B (mg kg^{-1})	2.5	1.7	5.3	3.3	3.6	3.3

Plant analysis

The seasonal variation of the studied nutrients is typical for most deciduous trees and emphasizes the need to find an appropriate leaf sampling date for assessing the nutritional status of trees. Since leaf sampling was done according to the instructions of Beutel et al. (1983), our results can be used directly for comparison in terms of the optimal concentration of nutrients for optimal plant growth with those proposed by Brown (1994) at the fruit development stage (Table 2). The concentrations suggested by Brown (1994) are representative of fig trees without growth problems and not as concentrations for optimum plant yields.

Nitrogen

The mean leaf N concentration (on dry weight basis) between the flowering stage and postharvest stage ranged between 25 and 19 g kg^{-1}, 26 and 22 g kg^{-1}, 25 and 18 g kg^{-1} for the varieties White, Black Royal and White Royal, respectively. The N leaf content pattern at different development stages of all varieties is shown in Figure 1. The data clearly prove that N in the leaves of the studied fig cultivars decreased gradually until the end of the growing season (Figure 1), probably due to the mobilization of N to the

Table 2

Mean leaf concentration differences between the studied fig varieties at the same development stage

Stage	Variety	N	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
		(g kg^{-1} DW)					(mg kg^{-1} DW)				
Flowering	W#	25	1.3*a*	18*a*	20a	2.7*a*	147	35*a*	10	53*a*	23
Flowering	BR	26	1.4*b*	19*b*	23b	3.4*b*	155	39*b*	8	66*b*	26
Flowering	WR	25	1.2*c*	17*c*	26c	4.3*c*	127	44*c*	11	96*c*	23
Fruit development	W	22*a*	0.9	15*a*	30a	3.6*a*	88	40*a*	18*ab*	70*a*	37*a*
Fruit development	BR	23*b*	0.9	13*ab*	31a	2.8*b*	80	43*a*	15*b*	87*a*	49*b*
Fruit development	WR	19*c*	0.8	11*b*	39b	4.2*a*	75	56*b*	19*a*	131*b*	33*a*
Fruit maturity	W	22*a*	1.0*a*	17*a*	28	3.1*a*	85	27*a*	16*a*	76*a*	40*a*
Fruit maturity	BR	23*a*	1.0*a*	13*b*	28	2.5*b*	85	30*ab*	14*ab*	78*a*	56*b*
Fruit maturity	WR	19*b*	0.9*b*	12*b*	31	4.1*c*	73	37*b*	12*b*	119*b*	38*a*
Postharvest	W	19*a*	1.1*a*	13*a*	29	2.9*a*	107*a*	42	9	61*a*	40*a*
Postharvest	BR	22*b*	1.1*a*	10*b*	29	2.5*a*	77*b*	41	9	52*a*	53*b*
Postharvest	WR	18*a*	0.9*b*	11*b*	30	4.5*b*	84*ab*	48	9	88*b*	47*a*

W# = White, BR = Black Royal, WR = White Royal

Column means followed by different letters are significantly different, according to the Duncan's multiple range test, at $p \leq 0.05$. Column means without letters indicate no significance of differences by the Duncan's test at $p \leq 0.05$.

growing fruits and other parts of the tree. The mean N leaf content at the flowering development stage was relatively high in all varieties and no differences were observed between varieties; in the next stage i.e. fruit development, the leaf N content decreased significantly in all varieties, and significant differences were observed between the varieties (Table 3). At the fruit maturity and postharvest stages, the N leaf content remained constant in the varieties Black Royal and White Royal but declined in the White variety.

The N mean leaf content (18 to 21 g kg$^{-1)}$ fluctuated within the same values with those suggested by Brown (1994) at the fruit development stage for optimal plant growth (Table 3). Generally, the level of N content during the growing period was sufficient compared with corresponding the levels of sufficiency in various deciduous trees (Therios, Dimassi-Theriou 2013).

Phosphorus

The P content in fig leaves between the flowering and postharvest stage ranged between 1.3 and 1.1 g kg^{-1}, 1.4 and 1.1 g kg^{-1} and 1.2 and 0.9 g kg^{-1},

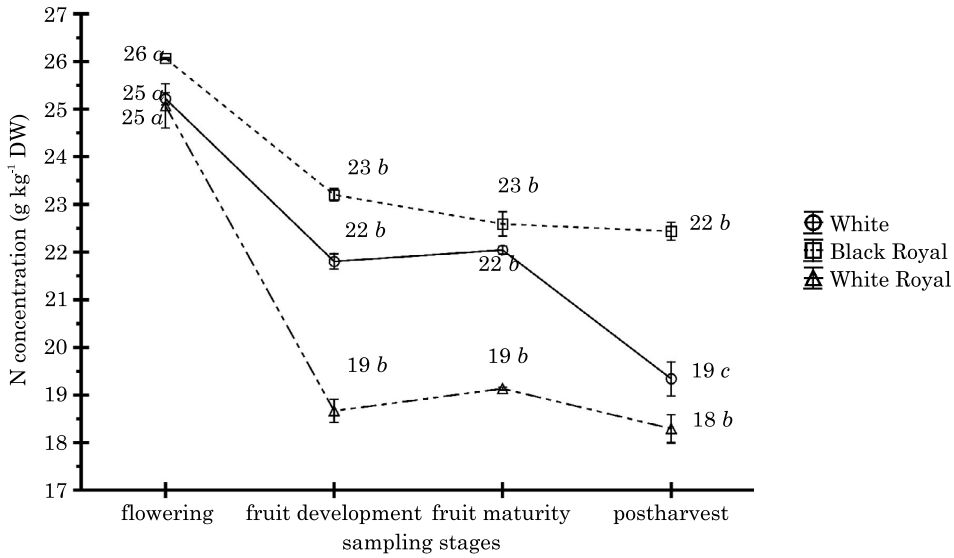

Fig. 1. Changes in nitrogen (N) concentration in the leaves of 3 fig varieties during a growth cycle. Error bars represent standard error of the mean of 5 replicates. Means at different sampling time for each cultivar followed by the same letter are not significantly different according to the Duncan's multiple range test at $p \leq 0.05$

Table 3

Mean fig leaf nutrient concentration range at the fruit development stage for all varieties studied

Nutrient	Data-1#	Data-2	Data-3	Data-4
N (g kg^{-1} DW)	19-23	18-21	18-26	10-60
P (g kg^{-1} DW)	0.8-0. 9	1.1-1.3	0.8-1.4	2-5
K (g kg^{-1} DW)	11-15	07-13	10-19	15-40
Ca (g kg^{-1} DW)	30-39	27-33	23-39	5-15
Mg (% DW)	3-4	6-8	2-5	1.5-4
Fe (mg kg^{-1} DW)	75-88	98-112	73-155	50-75
Zn (mg kg^{-1} DW)	40-43	10-14	27-56	15-50
Cu (mg kg^{-1} DW)	15-19	5-7	9-19	2-20
Mn (mg kg^{-1} DW)	70-131	65-115	52-131	10-50
B (mg kg-1 DW)	75-88	55-145	23-56	20

(Data-1) compared with mean leaf fig concentration range for optimum growth (Data-2) proposed by Brown (1994). Mean leaf fig concentration range during a growth period for all varieties studied (Data-3) compared with the mean leaf concentrations range (Data-4) proposed by Miller, Benton Jones jr. (1996) for sufficient growth of many trees.

for the varieties White, Black Royal and White Royal, respectively (Figure 2). The mean leaf P content decreased significantly in the fruit development stage then increased and remained constant until the end of the studied pe-

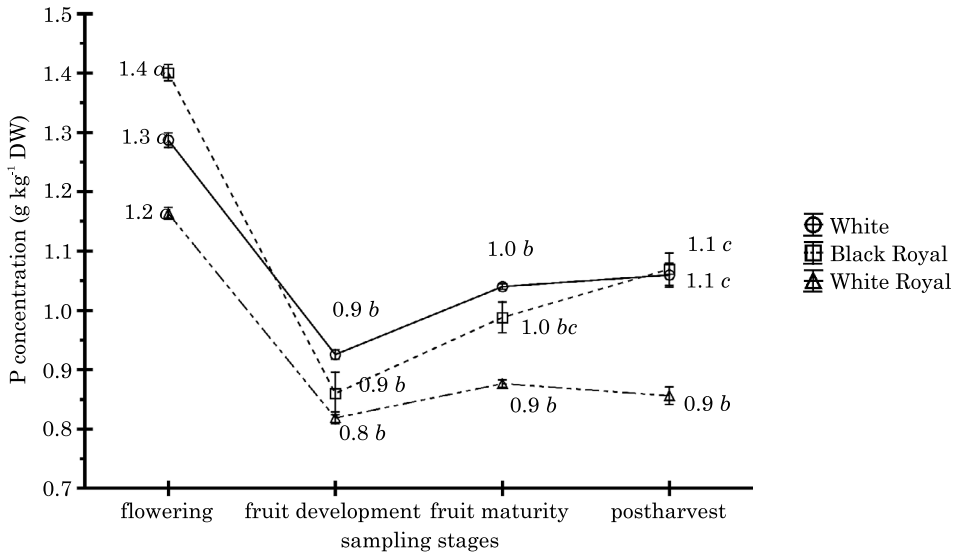

Fig. 2. Changes in phosphorus (P) concentration in the leaves of 3 fig varieties during a growth cycle. Error bars represent standard error of the mean of 5 replicates. Means at different sampling time for each cultivar followed by the same letter are not significantly different according to the Duncan's multiple range test at $p \leq 0.05$

riod (Figure 2). In the flowering stage, significant differences were detected between the varieties but there were no such differences in the fruit development stage (Table 3). The value of the P content in the flowering stage of the Black Royal variety is greater than in the other two varieties. In the next development stages the leaf P content decreased and then remain constant in the White Royal variety, but for the other two varieties, the mean P leaf content increased at the fruit maturity stage and then remained constant until the end of growing season (Figure 2). The mean P values in all the varieties were generally low compared to most of other tree crops (Beutel et al. 1983, Reuter, Robinson 1986). Proebsting, Warner (1954), Aksoy et al. (1987), Askin et al. (1998), Ersoy et al. (2003), Hakerlerler et al. (1998), and Brown (1994) reported similar P mean leaf content for figs during a growing season.

Potassium

The pattern of K concentrations in the leaves of the studied fig varieties was similar with that of N and P (Figure 3), i.e. it decreased with the increasing leaf age. The K concentration at the flowering and postharvest stage ranged between 18 and 13 g kg^{-1}, 19 and 10 g kg^{-1}, 17 and 11 g kg^{-1} for the varieties White, Black Royal and White Royal, respectively (Figure 3). The potassium leaf concentration decreased from flowering to fruit maturity in all varieties. In the White and Black Royal varieties after the fruit devel-

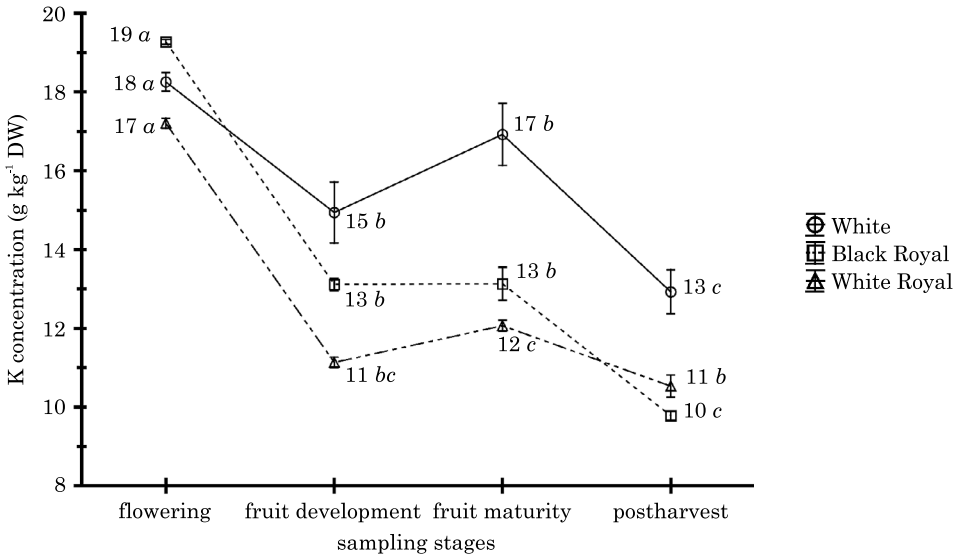

Fig. 3. Changes in potassium (K) concentration in the leaves of 3 fig varieties during a growth cycle. Error bars represent standard error of the mean of 5 replicates. Means at different sampling time for each cultivar followed by the same letter are not significantly different according to the Duncan's multiple range test at $p \leq 0.05$

opment stage, the K leaf concentration remained constant until fruit maturity and then declined. In the White Royal variety, the K leaf concentration after fruit development increased until fruit maturity and then remained constant (Figure 3). Significant differences in the K leaf concentration between all the varieties were observed in the fruit development stage but no differences were detected between the White and Black Royal. In the next stages, differences were observed between White and White Royal and between Black Royal and White Royal (Table 3). As with most deciduous crop species, tissue K concentrations decline as the season progresses. In our study, this decline is particularly marked in all varieties, and the same was reported by BROWN (1994). The potassium leaf content at the fruit development stage fluctuated approximately in the same range as indicated by BROWN (1994), but the mean K fig leaf content for the growing season was at lower levels than the K content in other fruit tree species (MILLS, BENTON JONES JR 1996). The low K leaf content in comparison with other fruit tree species is possibly associated with the high demand for K by the fig fruit because K plays an important role in the sun scaled development on fig fruit (AKSOY et al. 1987).

Calcium

The mean leaf Ca concentration at the flowering, fruit development, fruit maturity and postharvest stage ranged between 20 and 29 g kg^{-1},

23 and 29 g kg^{-1}, and 26 and 30 g kg^{-1} for varieties White, Black Royal and White Royal, respectively (Figure 4). The pattern of Ca concentrations in leaves during the growing season is presented in Figure 4. It demonstrates that the Ca leaf concentration increased significantly at the fruit development stage in the White and White Royal varieties but the maximum leaf Ca concentration in the Black Royal variety was observed in the late flowering (early June). The Ca leaf concentration in the White and Black Royal varieties after the fruit development stage remained constant. Significant differences in Ca leaf concentrations between all the varieties were detected only in the flowering stage (Table 3). The leaf concentration of Ca decreased rapidly after the second part of the flowering stage in Black Royal and after the fruit development stage in White Royal (Figure 4). ERSOY et al. (2003), and BROWN (1994) reported that the Ca content is low in young leaves but increases rapidly. Calcium leaf concentrations in all samplings and studied varieties were above the level of adequacy for other deciduous crops and above the level for optimum growth at the fruit development stage (Table 2).

Magnesium

The mean leaf Mg concentration in fig leaves at the flowering, fruit development, fruit maturity and postharvest stage ranged between 2.7 and 2.9 g kg^{-1}, 3.4 and 2.5 g kg^{-1}, 4.3 and 4.5 g kg^{-1} for White, Black Royal and White Royal, respectively (Figure 5). Significant differences in mean leaf

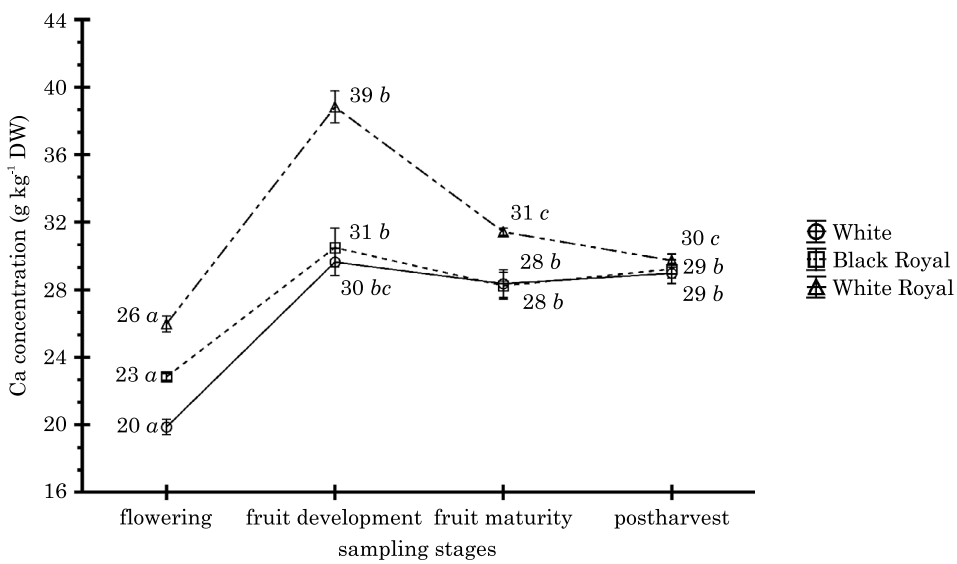

Fig. 4. Changes in calcium (Ca) concentration in the leaves of 3 fig varieties during a growth cycle. Error bars represent standard error of the mean of 5 replicates. Means at different sampling time for each cultivar followed by the same letter are not significantly different according to the Duncan's multiple range test at $p \leq 0.05$

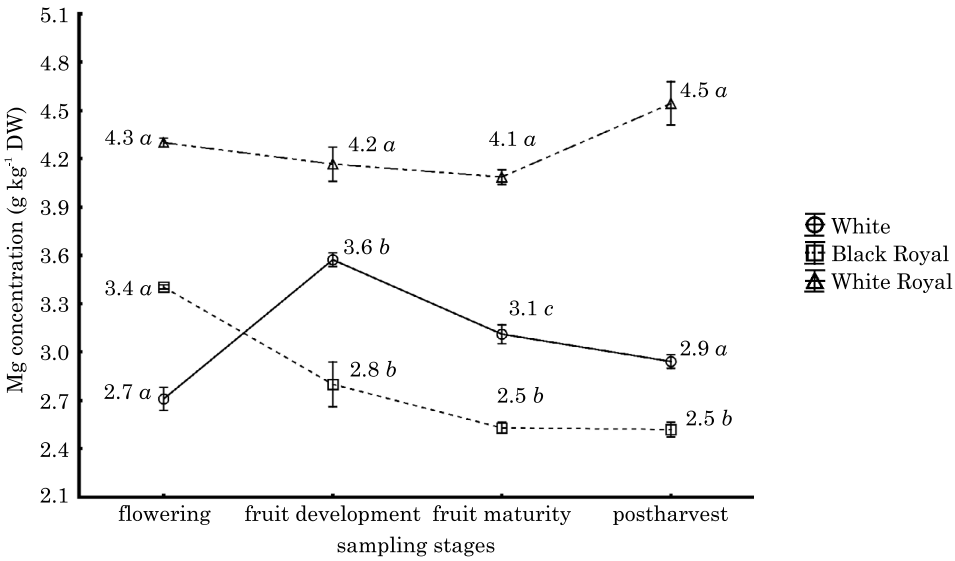

Fig. 5. Changes in magnesium (Mg) concentration in the leaves of 3 fig varieties during a growth cycle. Error bars represent standard error of the mean of 5 replicates. Means at different sampling time for each cultivar followed by the same letter are not significantly different according to the Duncan's multiple range test at $p \leq 0.05$

Mg concentrations between all the varieties were observed at the flowering and fruit maturity stages. In the fruit development stage, a lower leaf Mg concentration was observed in the Black Royal variety (Table 3). Leaf Mg concentrations in White Royal and 'Black Royal, increased in the second part of the flowering stage and then decreased. In the White variety, the Mg leaf concentration increased from the flowering to fruit development stage and then decreased until the end of the growing period (Figure 5). Magnesium leaf concentrations in all samplings and studied varieties were concordant with the adequacy level for other deciduous crops and but much lower than the level for optimum growth at the fruit development stage (Table 2). As the age of leaves increased, the Mg content in all the studied varieties decreased. These results are opposite to the results of Ersoy et al. (2003) and Brown (1994).

The N, P, K leaf content decreased from the flowering to postharvest stage. A similar pattern for N, P, K was reported by Brown (1994) for Sarilop fig leaves and by Ersoy et al. (2003) for Yesilguz fig leaves. Smith et al. (1987), Fatta del Bosco et al. (1990), Mirdehghan, Rahemi (2007), Nachtigall, Dechen (2006) reported that leaf N, P, K concentrations decreased during the growing season in kiwifruit, almond, pomegranate, and apple trees, respectively.

Micronutrients

The patterns of mean Fe, Zn, Cu, Mn, and B leaf concentrations throughout the growing season are presented in Figures 6-10. The data show

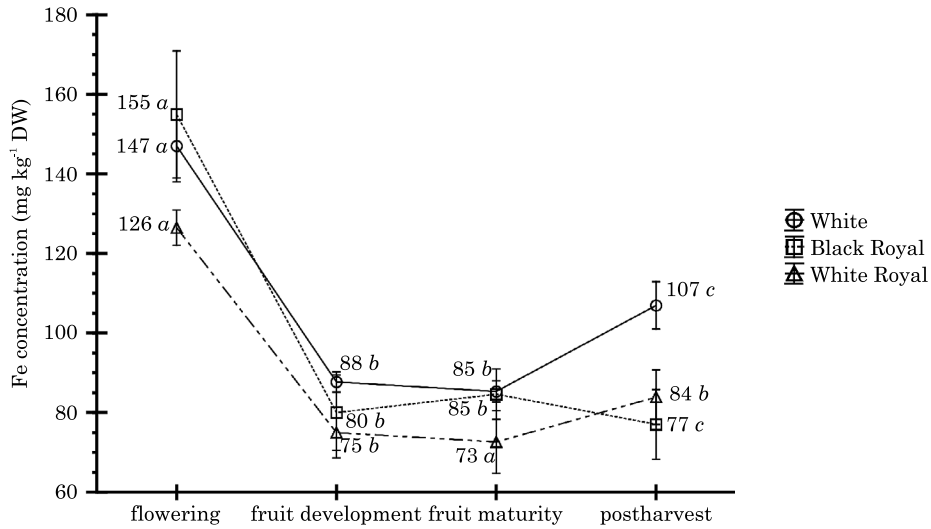

Fig. 6. Changes in iron (Fe) concentration in the leaves of 3 fig varieties during a growth cycle. Error bars represent standard error of the mean of 5 replicates. Means at different sampling time for each cultivar followed by the same letter are not significantly different according to the Duncan's multiple range test at $p \leq 0.05$

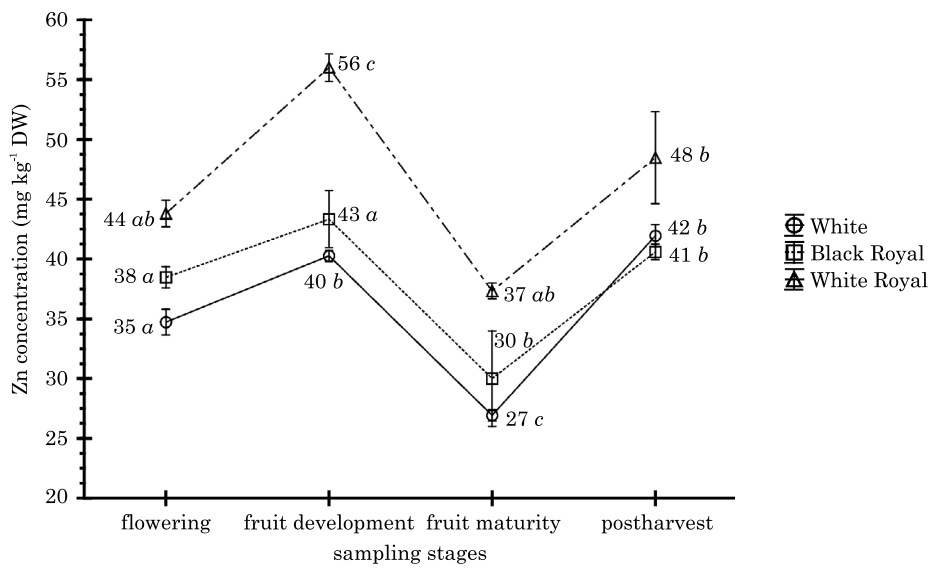

Fig. 7. Changes in zinc (Zn) concentration in the leaves of 3 fig varieties during a growth cycle. Error bars represent standard error of the mean of 5 replicates. Means at different sampling time for each cultivar followed by the same letter are not significantly different according to the Duncan's multiple range test at $p \leq 0.05$

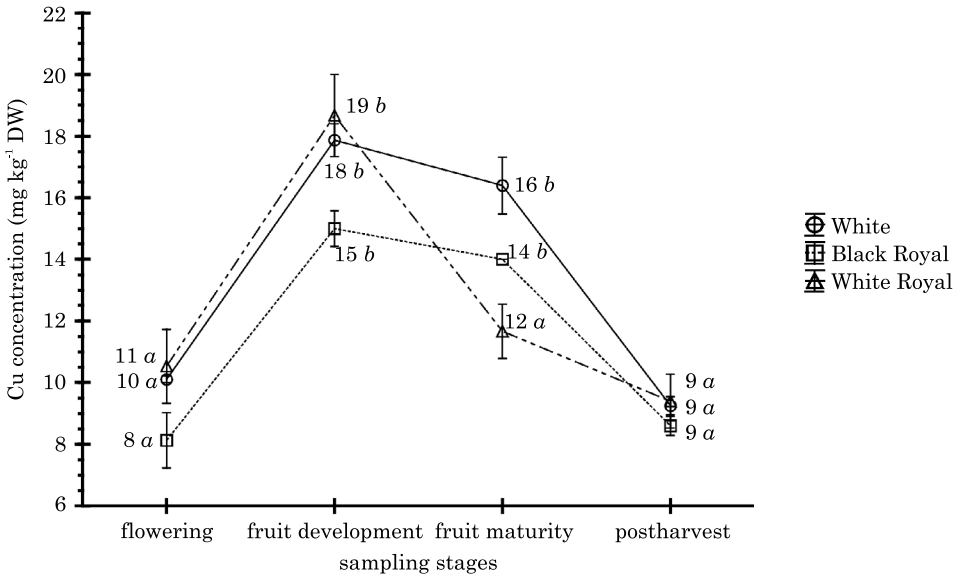

Fig. 8. Changes in copper (Cu) concentration in the leaves of 3 fig varieties during a growth cycle. Error bars represent standard error of the mean of 5 replicates. Means at different sampling time for each cultivar followed by the same letter are not significantly different according to the Duncan's multiple range test at $p \leq 0.05$

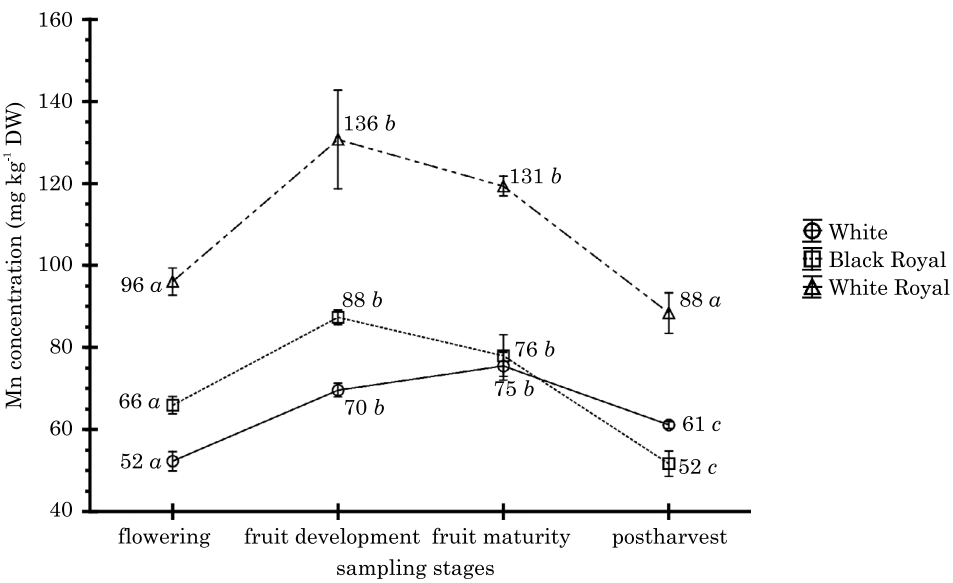

Fig. 9. Changes in manganese (Mn) concentration in the leaves of 3 fig varieties during a growth cycle. Error bars represent standard error of the mean of 5 replicates. Means at different sampling time for each cultivar followed by the same letter are not significantly different according to the Duncan's multiple range test at $p \leq 0.05$

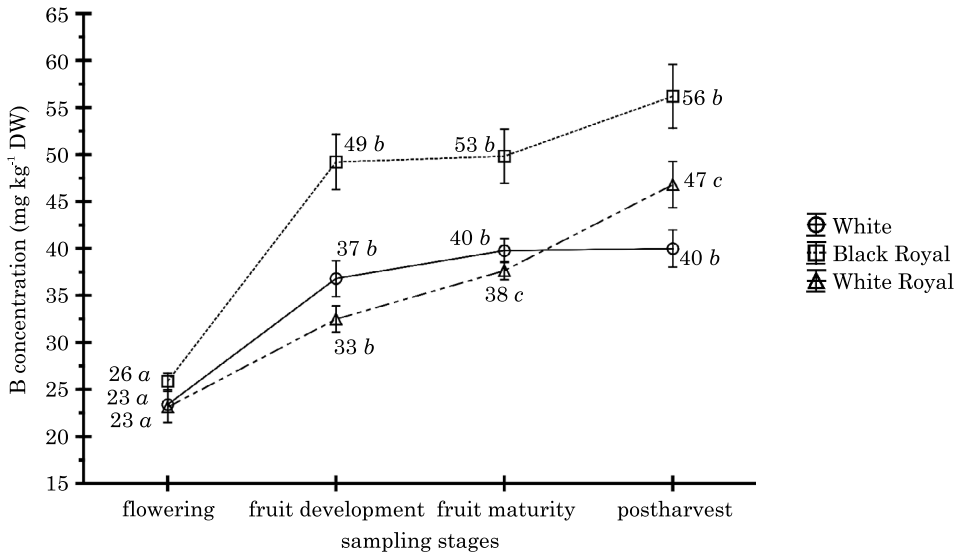

Fig. 10. Changes in boron (B) concentration in the leaves of 3 fig varieties during a growth cycle. Error bars represent standard error of the mean of 5 replicates. Means at different sampling time for each cultivar followed by the same letter are not significantly different according to the Duncan's multiple range test at $p \leq 0.05$

that their seasonal changes appear to be somewhat irregular and depended on the development stage and variety.

Iron

The mean leaf Fe concentration in fig leaves between the flowering and postharvest stage ranged between 147 and 107 mg kg^{-1} (DW), 155 and 77 mg kg^{-1} (DW) and 126 and 84 mg kg^{-1} (DW), for the varieties White, Black Royal and White Royal, respectively (Figure 6). The leaf Fe concentration decreased from the flowering to fruit development stage in all the varieties, then the leaf Fe concentration in the White and the White Royal varieties remained constant until fruit maturity and increased in the postharvest stage. In the Black Royal variety, the leaf Fe concentration remained constant in all stages after the development stage (Figure 6). No differences in leaf Fe concentrations between the varieties existed at the flowering stage, but significant differences between the varieties were observed only in the fruit development stage (Table 3). The fig leaf Fe content for all the varieties was lower for optimum growth at the development stage and higher than in other tree species during a growing season (Table 2).

Zinc

The mean leaf Zn concentration in fig leaves at the flowering, fruit development, fruit maturity and postharvest stage ranged between 35 to 42, 38

to 41, and 44 to 48 mg kg^{-1} (DW) for White, Black Royal and White Royal, respectively (Figure 7). Significant differences in mean leaf Zn concentrations were observed between the varieties at the flowering and fruit development stages (Table 3). The mean leaf Zn concentration in all the varieties increased at the fruit development stage then decreased at fruit maturity and increased at the postharvest stage (Figure 7). The fig Zn leaf content ranged from 40 to 43 at the fruit development stage and would be considered high relative to the Zn content (10 to 14 mg kg^{-1}) proposed by BROWN (1994) for optimum growth. The mean Zn fig leaf content during the growing season was within a sufficient range of concentrations in comparison with the Zn content in other fruit tree species (Table 2).

Copper

The mean leaf Cu concentration in fig leaves at the flowering, fruit development, fruit maturity and postharvest stage ranged between 10 to 9, 8 to 9, and 11 to 9 mg kg^{-1} (DW) for White, Black Royal and White Royal, respectively (Figure 8). The mean Cu leaf concentration increased from fruit development to fruit maturation and then declined until postharvest (Figure 8). ERSOY et al. (2003) reported that the Cu concentration in fig leaves decreased with the increasing age of leaves. Differences in mean leaf Cu concentrations between the varieties were observed in fruit development and fruit maturity samplings; specifically, there were differences between Black Royal and White Royal during the fruit development stage, and between White and White Royal in the fruit maturity stage (Table 1). The fig leaf Cu content in all the varieties was much higher than the one suggested at the development stage for optimum growth. Cu concentrations were found to be adequate in our study. The mean Cu fig leaf content during the growing season was sufficient compared to the Cu content in other fruit tree species (Table 2).

Manganese

The mean leaf Mn concentration between the flowering and postharvest stage ranged between 52 and 61, 66 and 52, 66 and 98 mg kg^{-1} (DW) for White, Black Royal and White Royal, respectively (Figure 9). Differences in mean leaf Mn concentrations between the varieties were observed at the flowering and fruit development stages (Table 3). In all the varieties, the mean leaf Mn concentration increased from the flowering to fruit development stage and then decreased until postharvest (Figure 9). The mean Mn fig leaf content throughout the growing season ranged from 52 to 131 mg kg^{-1}, which is much higher than in many other deciduous trees. Manganese tended to be higher at the fruit development stage than levels indicated for optimum growth (Table 2).

Boron

The mean leaf B concentration increased with the increasing age of leaves and reached at postharvest 40, 56 and 47 mg kg^{-1} (DW) for White, Black Royal and White Royal, respectively. The boron leaf content increased in all the fig varieties until the end of the studied period, rising by 42%, 50%, 54% for the White, White Royal and Black Royal, respectively. The B leaf concentration in all stages and all varieties accumulated with time and the values were much higher than for B extracted from the soil (Table 3). These findings are particularly noteworthy since they indicate significant accumulation of B. Significant differences in leaf B concentrations between Black Royal and the other two varieties existed in all the development stages except flowering (Table 1). Boron fig leaf content was within a range of sufficient concentrations (Table 2).

CONCLUSIONS

Fluctuations in concentrations of the investigated elements in the fig varieties studied were influenced by the vegetative growth and variety. Macronutrients (N, P, K, Ca, Mg) as well as micronutrients (Fe, Zn, Cu, Mn, B) show fluctuations during the study. The variation of the content of nutrients throughout the growing season is possibly due to their high uptake during the development of new vegetative organs, flowers and during the fruit production and maturation period. The determined values for macro- and micronutrients in fig leaves were all above the threshold limits of deficiency except for P and Mg.

The measured values plotted versus time can be useful in explaining several phenomena during the bearing cycle of the fig tree. These measurements could also be used to support decisions about fertilization plans, ensuring an optimum fertilizer composition and schedule, according to the requirements of the plants.

Fig trees are possibly a boron accumulator.

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