

## **ROOTSTOCK AND CULTIVAR EFFECT ON MINERAL NUTRITION, SEASONAL NUTRIENT VARIATION AND CORRELATIONS AMONG LEAF, FLOWER AND FRUIT NUTRIENT CONCENTRATIONS IN APPLE TREES**

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### **Abstract**

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This study aimed to investigate differences of nutrient concentrations among rootstocks and cultivars even they are grown in the same conditions. The other goal of this experiment was to determine seasonal variations of leaf nutrient concentrations during growing period. Determining relations among leaf, flower and fruit nutrient concentrations was another purpose of this study. For these purposes four rootstocks and cultivars were used. Among the rootstocks, MM106 had the highest level of nutrient concentrations whereas M9 had the lowest. Mondial Gala cultivar had higher nutrient concentration compared to others. The highest leaf mineral nutrient concentrations were determined on July in general.

Key words: apple, rootstock, cultivar, seasonal variations, nutrient concentrations

### **Introduction**

Since plant cultivars and rootstocks show different response to nutrients, plant rootstock and cultivar are main factors affecting plant growth. Plant nutrient concentrations may differ even if they are grown in the same conditions (Kacar, 1995; Bergmann, 1992; Marshner, 1995). Numerous studies have shown that rootstocks can affect tree growth, flower development, yield and fruit quality of different apple cultivars (Seeley et al., 1979; Westwood et al. 1986; Schechter et al., 1991; Gao et al., 1992; Fallahi et al., 1994; Hirst and Ferree 1995) Rootstocks also affect scion leaf mineral concentration in apples (Poling and Oberly,

1979; Tagliavini et al., 1992). Abdalla et al. (1982) reported that 'Delicious' apple trees on dwarfing rootstocks had more yield efficiency and higher leaf Mn but lower leaf K than trees on vigorous rootstocks. Fallahi et al. (1984) observed that 'Starkspur Golden Delicious' apple tree on M.26 had higher leaf Mg than those on the other tested rootstocks. The nutrient uptake and translocation ability of the different plant cultivars and their rootstocks must also be taken into account for plant growth because these differences can affect yield and quality (Giordano and Mortvedt, 1974). By determining which genotype is sensitive or tolerant to which nutrient, it would be possible to choose which cultivar should be grown for higher yield

and quality. To get a better quality of fruits, the researchers should take into consideration mineral nutrient content of apple (Campeanu et al., 2009). Also determining plant nutrient uptake capacity is important to know how much nutrient is required for a cultivar (Jimenez et al., 2004).

Foliar analysis is widely used to evaluate the nutritional status of apple trees. Determining fruit nutrient concentrations has received special attention, since it can provide information on fruit quality based on previously known adequate and critical nutrient levels (Marcelle, 1984; Suzuki and Argenta, 1994; Ernani et al., 2002; Nachtigall and Dechen, 2006). Flower analysis can also provide information for nutritional status of apple trees. The use of flower analysis as a diagnostic tool would enable detection of mineral deficiency at an earlier stage. The early detection and correction of Fe deficiency allowed measuring the influence of Fe chlorosis on fruit quality (Sanz et al., 1997). By correcting Fe deficiency, fruit size was doubled and the delay in fruit ripening associated with Fe deficient trees was avoided (Bouranis et al., 2001).

The nutrient accumulation curves of apple trees are good indicators of nutrient requirement in each plant development stage (Nachtigall and Dechen, 2006). Seasonal changes in the distribution of nutrients in fruit trees have been reported in previous works (Clark and Smith, 1988, 1990; Haynes and Goh, 1980; Liu and Wang, 1989; Nachtigall and Dechen, 2006; Thomidis et al., 2007; Hirzel and Best, 2009).

This study aimed to investigate the differences of nutrient concentrations among rootstocks and cultivars grown in the same conditions before making fertilization programs. The other goal of this experiment was determining seasonal variations of leaf nutrient concentrations to define nutrient needs related to growing period. Determining the relations among leaf, flower and fruit nutrient concentrations was another purpose of this work.

## Materials and Methods

Study was conducted at Egirdir Horticultural Research Institute, Isparta-Turkey. The experimental soil was loam having pH 8.3 (1:2.5 soil to water ratio), 10% CaCO<sub>3</sub> (Calsimetric method), 2.5% organic matter (Walckey and Black method, Jackson, 1962), 18 kg ha<sup>-1</sup> 0.5 M NaHCO<sub>3</sub> extractable P (Olsen et al., 1954), 163 kg ha<sup>-1</sup>, 423 kg ha<sup>-1</sup> 1N NH<sub>4</sub>OAC exchangeable K and Mg (Atomic absorption spectrophotometer methods, Knudsen et al., 1982). The available Fe, Cu, Zn and Mn as determined in DTPA extract (Lindsay and Norwell, 1978) on Atomic absorption spectrophotometer were 14.3, 3.6, 0.8 and 10.6 mg kg<sup>-1</sup>, respectively.

The experiment was carried out in a split-plot design having 4 replications (blocks). As basal fertilization, 30 kg ha<sup>-1</sup> N, 42.2 kg ha<sup>-1</sup> P, 40 kg ha<sup>-1</sup> K were applied from ammonium nitrate, mono ammonium phosphate and potassium nitrate respectively.

In this study M9 (dwarf), M26 (dwarf), MM106 (semi dwarf), MM111 (strong) rootstocks and Granny Smith (GS), Mondial Gala (MG), Lutz Golden (LG) and Skyline Supreme (SS) cultivars were used. Plants were drip irrigated.

### *Sampling and preparation for analysis*

Flower samples were sampled in April and leaf samples were taken in three different seasons (May, July and August). Fruit samples were taken in the middle of the harvest period for each cultivar. Before analysis, samples were washed thoroughly with fountain water, dilute acid (0.2N HCl) and distilled water to remove surface residues, then they were kept at 65±5 C<sup>0</sup> until they dried and were grounded for nutrient analysis. Nitrogen (N) concentration in samples was determined according to Modified Kjeldahl method in which 0.5 g sample digested in concentrated H<sub>2</sub>SO<sub>4</sub> and distilled with NaOH (40%). The ammonium N was fixed in H<sub>3</sub>BO<sub>3</sub> (2%) and titrated with 0.1N

H<sub>2</sub>SO<sub>4</sub>. In order to determine Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Iron (Fe), Zinc (Zn), Copper (Cu) and Manganese (Mn) concentrations, 1 g of samples were dry ashed at 500 ± 50 °C for 8 h, and the ash was dissolved in 4 ml 3N HCl and filled up with pure water. Phosphorus contents of samples were determined by vanadate-molybdate colorimetric method. Potassium, Ca, Mg, Fe, Zn, Cu and Mn concentrations were determined using atomic absorption spectrophotometer (Kacar and Inal, 2008).

### ***Statistical analysis***

Nutritional statuses of apple plants were evaluated depending on the values given by Jones et al. (1991). Analysis of variance was performed on the data obtained from the treatments. The level of the significance (LSD at P< 0.05) was used in the MSTAT-C to test significance (Freed and Eisensmith, 1989).

## **Results and Discussion**

### ***Seasonal variation of leaf nutrient concentrations***

When nutrient concentrations of apple leaves were evaluated individually at each growth period, it was seen that nutrient concentrations (except for N and Mg) of different rootstocks significantly varied depending on growing period generally. As seen in Table 1 among rootstocks semi-dwarf rootstock, MM106 and strong rootstock MM111 had significantly higher mineral nutrients, compared to fully-dwarf rootstock M9 and dwarf rootstock M26 throughout whole seasons generally.

Leaf P and K concentrations of strong and semi-dwarf rootstocks were higher than that of other two fully-dwarf and dwarf (M9 and M26) rootstocks at three growth periods. Except for Ca, Mg, and K concentrations in late period of August and K, Mg and Zn concentrations in early period of May, differences of leaf nutrient concentrations were

significantly affected by rootstocks. While MM111 rootstock had the highest Ca concentration in May, MM106 rootstock had the highest in July; all rootstocks had similar Ca concentrations in August period. In terms leaf Mg concentration there was no significant difference among rootstocks for all periods. In May and July periods strong rootstock, MM111 had the highest concentrations of Fe on leaf but, MM106 and M26 rootstocks had higher Fe concentrations in August compared the others. While the highest Cu concentrations of rootstocks varied for each period, the lowest Cu concentration rootstock was observed in MM106. Leaf Zn concentrations in May did not vary among the rootstocks. Also leaf Zn concentrations of M9, M26 and MM111 in July and M26, MM106 and MM111 rootstocks in August periods did not differ. Semi-dwarf rootstock, MM106 had the highest Mn concentrations among the rootstocks. But the lowest Mn concentrations were determined at the leaf of dwarf M9 rootstock.

Leaf N, Mg and Cu concentrations of cultivars did not differ among sampling period, however, other nutrient concentrations significantly varied depending on the cultivars. In general leaves of MG contained higher mineral nutrients compared to the other cultivars.

Mean values representing rootstocks and cultivars showed that leaf nutrient concentrations for all nutrients indicated differences among the seasons, and these variations were found significant (Table 1).

Average values indicated that the highest levels of N, P, K, Mg, Fe and Mn concentrations were reached in July, mid-season of vegetation, but through the end of the season, they began to decrease. Despite the fact that leaf Cu and Zn levels showed decreasing tendency, with the progressing seasons Ca concentration increased.

Rootstock and variety effects on nutrient concentration of apple trees can be explained with the genetic effect leading to different nutrient uptake capacity (Kennedy et al., 1980; Tsipouridis and Thomidis, 2005; Jimenez et al., 2007,

**Table 1**  
**Rootstock and cultivar effect on seasonal variation of leaf nutrient concentrations of apple trees**

Nutrient	Period	Rootstocks				Cultivars				Means
		M9	M26	MM106	MM111	GS	MG	LG	SS	
N %	May	2.0	2.0	2.1	2.1	2.0	2.0	2.1	2.1	2.1B**
	July	2.2	2.2	2.3	2.3	2.2	2.2	2.3	2.3	2.3A
	August	1.9	2.0	2.0	2.0	1.9	2.0	2.0	2.0	2.0C
P %	May	0.13b*	0.13b	0.16a	0.16a	0.14b	0.17a	0.13b	0.14b	0.15B
	July	0.15b	0.15b	0.18a	0.19a	0.17a	0.19a	0.15b	0.18a	0.17A
	August	0.12b	0.13b	0.15a	0.15a	0.14b	0.16a	0.12b	0.14b	0.14C
K %	May	1.18	1.16	1.17	1.36	1.29	1.20	1.20	1.20	1.22B
	July	1.40b	1.49ab	1.49ab	1.58a	1.38c	1.58a	1.45bc	1.54ab	1.49A
	August	1.20	1.20	1.20	1.20	0.98b	1.43a	0.99b	1.40a	1.20B
Ca %	May	0.81ab	0.60c	0.65bc	0.89a	0.65b	0.74ab	0.86a	0.70ab	0.74C
	July	0.96ab	0.91b	1.03a	0.83b	0.78c	1.03a	1.06a	0.89 b	0.94B
	August	1.45	1.31	1.46	1.46	1.40ab	1.50a	1.58a	1.20 b	1.42A
Mg %	May	0.26	0.25	0.27	0.26	0.26	0.25	0.26	0.27	0.26C
	July	0.31	0.32	0.30	0.30	0.30	0.30	0.32	0.32	0.31A
	August	0.27	0.29	0.26	0.30	0.31	0.28	0.25	0.27	0.28B
Fe mg kg <sup>-1</sup>	May	116b	101b	128b	159a	130	125	122	127	126B
	July	123b	111c	142ab	148a	130ab	145a	119b	131ab	131A
	August	114b	145a	147a	123b	133	134	129	133	132A
Cu mg kg <sup>-1</sup>	May	9.7ab	8.6bc	7.2c	12.6a	9.4	9.6	9.4	9.7	9.5A
	July	6.5b	9.8b	3.9d	5.1c	6.1	6.3	6.7	6.1	6.3B
	August	6.2a	7.3bc	4.5c	6.0b	6.0	5.9	6.0	6.0	6.0B
Zn mg kg <sup>-1</sup>	May	25.8	24.9	26.1	27.6	26.0	25.8	26.1	26.5	26.1A
	July	22.0b	22.3b	25.7a	23.4b	24.1ab	24.9a	22.3b	22.2b	23.4B
	August	16.5b	18.8a	19.5a	20.0a	18.7b	21.4a	15.5c	19.1b	18.7C
Mn mg kg <sup>-1</sup>	May	46.0c	89.0b	125.0a	93.0b	93.0a	93.0a	75.0b	92.0a	88.3B
	July	77.0c	130.0b	177.0a	125.0b	132.0	135.0	116.0	126.0	127.3A
	August	69.0d	134.0b	197.0a	87.0c	135.0a	134.0a	103.0c	115.0b	121.8 A

\* differences between the same letters for each row are not significant. Values belonging rootstocks and cultivars were evaluated separately.

\*\* differences between the same letters are not significant.

Küçükyumuk and Erdal, 2009). Previous studies mentioned that, plants used different amount of soil or fertilizer nutrients even they were grown in the same condition (Kacar, 1995; Marschner, 1995; Erdal et. al., 2008).

Among rootstocks it was clearly seen that semi-dwarf rootstock, MM106 and strong rootstock

MM111, had significantly higher mineral nutrients, compared to dwarf rootstocks M9 and M26. There could be lower leaf nutrient concentrations due to less vigor of trees on M9 and M26 rootstocks (Fallahi et al., 2001). Differences in nutrient concentrations among rootstocks can also be explained with the structure of root systems,

**Table 2**  
**Rootstock and variety effect on flower and fruit nutrient concentrations of apple trees**

Nutrients	Plant organs	Rootstocks				Cultivars				Means
		M9	M26	MM106	MM111	GS	MG	LG	SS	
N %	Flower	1.80	1.80	1.90	1.90	1.80b	1.90a	1.90a	1.80a*	1.85A**
	Fruit	0.30b	0.30b	0.31ab	0.32a	0.28b	0.45a	0.24c	0.27b	0.31B
P %	Flower	0.12b	0.12b	0.12b	0.14a	0.13bc	0.15a	0.12c	0.13b	0.13B
	Fruit	0.18	0.18	0.12	0.16	0.12b	0.12b	0.18a	0.22a	0.16A
K %	Flower	1.10	1.10	1.09	1.00	0.90b	1.25a	0.90b	1.21a	1.07
	Fruit	1.10	1.10	1.10	1.20	0.97b	1.42a	1.02b	1.08b	1.12
Ca %	Flower	1.12b	1.12b	1.12b	1.42a	1.20	1.20	1.20	1.21	1.20A
	Fruit	1.13a	1.14a	0.95b	0.95b	1.19a	0.99bc	1.09ab	0.89c	1.04B
Mg %	Flower	0.27	0.27	0.26	0.26	0.25b	0.29a	0.27ab	0.25b	0.27A
	Fruit	0.19	0.19	0.19	0.20	0.21a	0.15b	0.20a	0.21a	0.19B
Fe mg kg <sup>-1</sup>	Flower	201b	202b	229a	220a	205b	202b	223a	222a	213A
	Fruit	48b	49b	51b	92a	62ab	49b	65a	64a	60B
Cu mg kg <sup>-1</sup>	Flower	15.5a	15.3a	11.5b	15.6a	12.2b	16.9a	17.0a	12.0b	14.5B
	Fruit	15.8b	15.2b	18.1ab	20.1a	15.2c	16.6b	17.4ab	19.8a	17.3A
Zn mg kg <sup>-1</sup>	Flower	36.4ab	29.9b	33.3ab	41.8a	33.0b	47.9a	28.9c	31.9b	35.4A
	Fruit	13.0b	14.1b	17.0a	17.0a	15.0b	17.0a	13.0b	15.0b	15.0B
Mn mg kg <sup>-1</sup>	Flower	92.9	76.5	89.2	79.5a	75.2b	77.8b	85.0a	100.0a	84.5A
	Fruit	35.8d	45.7c	66.7b	78.1a	45.0b	62.7a	53.6b	65.1a	56.6B

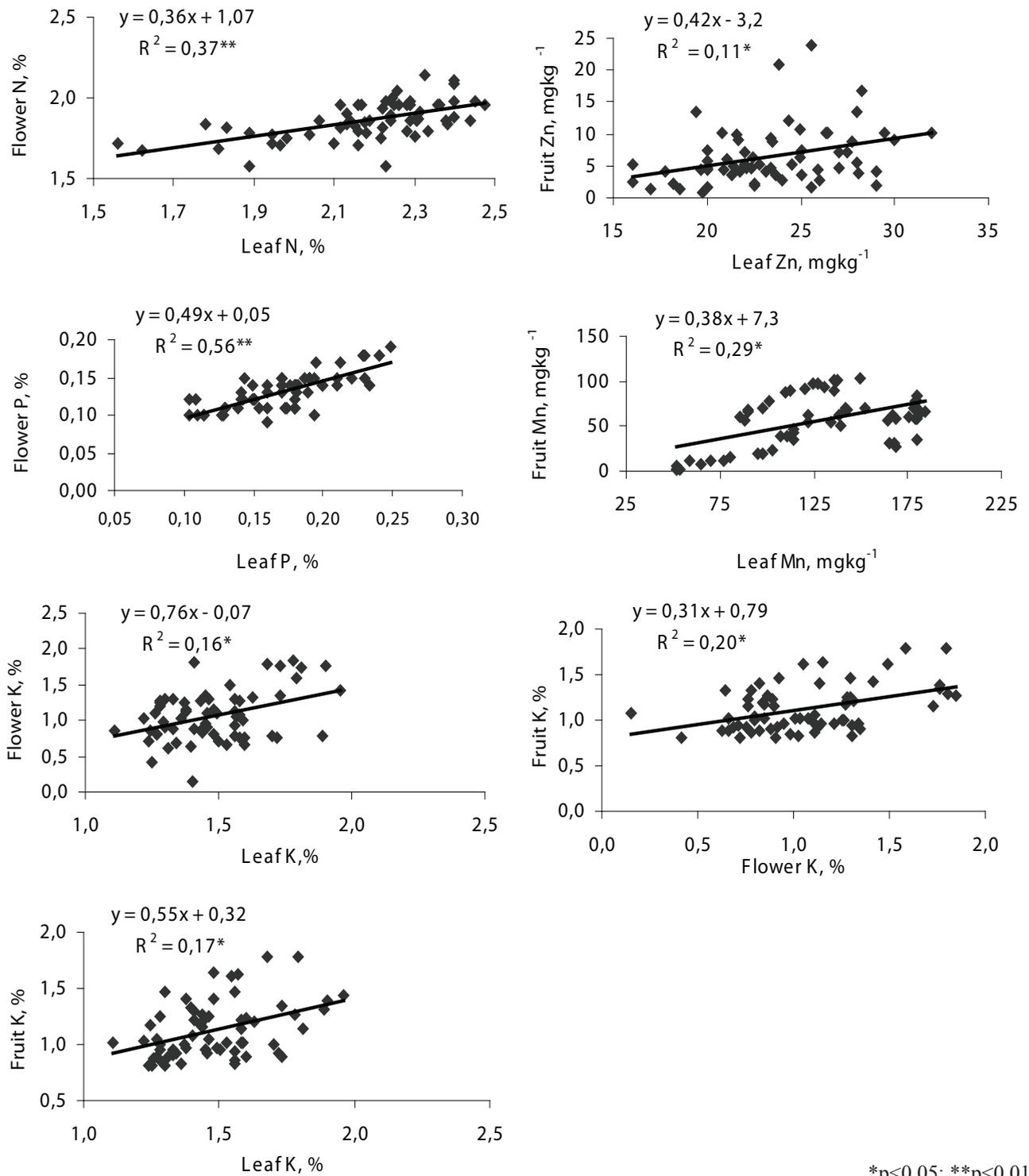
\* differences between the same letters for each row are not significant. Values belonging rootstocks and cultivars were evaluated separately.

\*\* differences between the same letters are not significant.

deviations of root cation exchange capacities, rhizosphere pH, characteristics of root exudates etc. Dwarf rootstocks such as M9 and M26 have smaller root systems, so it can be the major reason for having lower nutrient compared to others. In a study conducted by Erdal et al. (2008), it was found that leaf Fe concentrations of different apple cultivars showed differences. The differences among rootstocks uptake may be caused by different nutrient absorption capacities through the roots (Marschner et al., 1986a; Marschner et al., 1986b; Kayan, 2008). Planting space can also be another reason for nutrient uptake. Atkinson (1976), reported that at wider tree spacing, the tree root system was composed mainly of horizontal

roots with relatively few vertical sinkers, but at high densities it was composed mainly of vertical sinkers.

July sampling period had the highest N, P, K and Mg contents compared to the other leaf collecting times. Nitrogen, P, K, Mg concentrations decreased after 18 weeks after bloom. Young leaf tissues have lower water content and higher N, P and K concentrations, meanwhile older tissues are richer in Ca, Mn, Fe (Mengel and Kirkby, 2001). The concentrations of Ca increased from May to August. Nahtigal and Dechen (2006), found the same increase of Ca in apple trees and the increase can be explained with Ca immobility in plant tissues and no redistribution to other plant organs

\* $p < 0.05$ ; \*\* $p < 0.01$ **Fig. 1. Correlations among leaf, flower and fruit nutrient concentrations**

along the period. Our results agree with Nachtigall and Dechen (2006).

### ***Flower and fruit nutrient concentrations***

In general, flower and fruit nutrient concentrations were significantly affected by rootstocks (Table 2). However, rootstocks had similar N, K, Mg and Mn concentrations in flowers and P, K and Mg concentrations in fruits. Cultivar effect on flower and fruit nutrient concentration was found significant except, fruit Ca concentrations. According to mean values taken from the rootstocks and cultivars, N, P, K, Ca, Mg, Fe, Cu, Zn and Mn concentrations for flower were 1.85 %, 0.13 %, 1.07 %, 1.20 %, 0.27 %, 213 mg kg<sup>-1</sup>, 14.5 mg kg<sup>-1</sup>, 35.4 mg kg<sup>-1</sup> and 84.5 mg kg<sup>-1</sup> and for fruit were 0.31 %, 0.16 %, 1.12 %, 1.04 %, 0.19 %, 60 mg kg<sup>-1</sup>, 17.3 mg kg<sup>-1</sup>, 15.0 mg kg<sup>-1</sup> and 56.6 mg kg<sup>-1</sup>. When flower and fruit nutrient concentrations were compared, it was seen that fruit N, Ca, Mg, Fe and Zn concentrations were higher than flower nutrient concentration ( $p < 0.05$ ), but P, Cu and Mn concentrations of flower were higher than those of fruit. Potassium concentrations of flower and fruit were similar ( $p > 0.05$ ). Differences in flower and fruit nutrient concentrations depending on rootstocks and cultivars can be explained by genotypic variations as expressed above. In a study by Campeanu et al. (2009) it was expressed that nutrient concentration of apple fruits showed large variation depending on varieties.

### ***Correlations among leaf, flower and fruit nutrient concentrations***

On samples taken in July correlation tests were made in order to determine relations among leaf, flower and fruit nutrient concentrations. Significant positive correlations between leaf and flower N, P, K concentrations ( $p < 0.05$ ) were determined. Similarly, leaf and fruit K, Zn and Mn correlations were positive and significant. Only K concentrations in flower and fruit showed significant correlation (Figure 1).

Though there were significant correlations between leaf and flower N and K concentrations, these correlations were not strong enough. But correlation determined between leaf and flower P concentrations were strong and practically applicable ( $R^2 \geq 0.5$ ) to detect whether there was any treat of P deficiency at an earlier stage in apple trees. If average values of nutrient concentrations in leaves, taken in July, evaluated by the critical levels given by Jones et al. (1991) and Bergman (1992), it is clearly seen that leaf nutrient concentrations are between the optimum levels except for only Ca. Therefore, nutrient concentrations of flowers on trees having optimum leaf nutrient concentrations can be used for forecasting nutritional status of apple trees at early stage. Depending on previous expressions, if flower nutrient concentrations were higher than 1.85%, 0.13%, 1.07%, 0.27%, 213 mg kg<sup>-1</sup>, 14.5 mg kg<sup>-1</sup>, 35.4 mg kg<sup>-1</sup> and 84.5 mg kg<sup>-1</sup> for N, P, K, Mg, Fe, Cu, Zn and Mn, respectively, it can be said that there is no nutritional risk for mentioned nutrients. Similar methods of approach were also used in previous studies (Sanz and Montanes, 1995; Abadia et al., 2000)

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