# Diagnose apricot nutritional status according to foliar analysis

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**ABSTRACT**

This experiment was conducted in Cacak (Western Serbia) during 2004 and 2005 to determine the influence of Belosljiva, Dragacevka, Stanley, Kolenstockzwetsche, Wangenheim, Pozegaca, and Kapavac interstocks budded on Myrobalan seedlings on the seasonal changes, leaf macronutrient contents at 120 days after full bloom (DAFB) and deviation from optimum percentage (DOP) of Vera apricot cultivars. The macronutrients analyzed were N, P, K, Ca, and Mg. Nitrogen was consistently decreased during the vegetative cycle on all interstocks, while leaf P, Ca, and Mg had a tendency of increasing, except P on Kapavac. Potassium had a tendency to increase from 60 to 150 AFB, and decreased through 180 DAFB. Leaf N at 120 DAFB was higher in 2005, and P, K, Ca, and Mg in 2004 on all interstocks. Leaf macronutrients were significantly influenced by interstocks, except K. On the basis of DOP index, leaf N, Ca, and Mg were lower than optimum on all interstocks in both years. Leaf P and K were higher than optimum. Stanley and Wangenheim showed the weakest balanced nutritional values than the rest of interstocks.

**Keywords**: DOP index; interstocks, leaf mineral analysis; *Prunus armeniaca* L.

Apricot (*Prunus armeniaca* L.) is a widely grown stone-fruit species in Serbia. There are many negative factors that limit its growing, such as blossoms killed by spring frosts, sudden (premature) wilting – Apoplexy, winter killing of flower buds prior to bloom, *Plum pox virus* infection in apricot trees and the absence of quality rootstock and modern growing technologies (Milošević et al. 2010). However, the fundamental problem is the choice of quality rootstock. The controversies regarding rootstocks for the apricot speak of the very complex nature of this problem and of the need to study it with a view to establishing the most suitable rootstocks for each apricot cultivar. In apricot orchards in Serbia dominant rootstock are Myrobalan seedlings (*Prunus cerasifera* Ehrh.). The numerous defects of Myrobalan as rootstock for apricot [incompatibility, high vigour, early onset and late end of vegetative cycle, and frequent presence of sudden (premature) wilting – Apoplexy] are to be eliminated or mitigated by the use of interstocks (Paunovic 1977).

Generally, interstocks are used to overcome incompatibility between the stock and the scion. Interstocks also affect precocity of bearing and fruit quality, and reduction of scion shoot growth (Parry and Rogers 1972). Interstocks affect seasonal changes and content of macro- and microelements in leaves of apricot (Paunovic and Bojic 1983, Bojic and Paunovic 1988), and the nutritional status of apricot trees (Güleryüz et al. 1996). From this point, it creates the basis for the determination of nutritional status at 120 days after full bloom (DAFB) using methods that consider time and nutrient balances such as Evolutive Nutrient Balance (ENB), Diagnosis and Recommendation Integrated System (DRIS), Deviation from Optimum Percentage (DOP and ΣDOP index) and others (Montañés et al. 1991, Lucena 1997, Sanz 1999, Zarrouk et al. 2005).

This research was aimed to study the interest of leaf analysis as a tool for the prognosis of nutritional deficiencies on apricot trees and confirm the influence of seven interstocks on the mineral uptake by tree. This work also evaluates leaf composition standards that were compiled from the literature, and a survey of the leaf composition of well-managed orchards was conducted for two seasons.

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## MATERIAL AND METHODS

**Study area and trial procedure**. The orchard trial of interstock was established at Prislonica near Cacak, Western Serbia, using Vera as the scion apricot cultivar (19 to 20 years after planting). The study of N, P, K, Ca, and Mg contents and their seasonal changes in the leaves of apricot cv. Vera, budded on seven plum cultivars as interstocks (Belosljiva, Dragacevka, Stanley, Kolenstockzwetsche, Wangenheim, Pozegaca, and Kapavac) was carried out in 2004–2005. Interstocks were budded onto Myrobalan rootstock and Vera cultivar was budded on them. The training system was open vase at planting distance 6 m × 4 m. Orchard management was consistent with standard practice, except irrigation, and fertilized with 500 kg/ha NPK (15:15:15) mineral fertilizer in autumn and with 300 kg/ha calcium ammonium nitrate (containing 27% of N) prior to the onset of the vegetative cycle.

The soil chemical analysis was repeated prior to trial establishment. Soil samples were taken from 0–30 cm depths. The samples were ground and sifted in a 2 mm mesh. Once homogenized, a 5 g sub-sample was dried at 105°C and ground in a Speck 8000 Mixer/Mill until the material passed through a mesh of 100 screens. A Pye glass electrode pH-meter-potentiometer (W.G. Pye, Cambridge, UK) was used to measure pH in KCl 0.01 mol/L. The organic matter content was determined according to the Walkley-Black method in an automatic analyzer (Shimadzu TOC 5000-A, Kyoto, Japan), and total N by the Kjeldahl method using sulphuric acid and a metal catalyst. Available P and K were determined by extraction with Al solution, as suggested by Egner et al. (1960), using spectrophotometry (MA 9510, Iskra, Kranj, Slovenia) with molybdate and flame photometry (Spekol, Carl Zeiss, Jena, Germany), respectively. The Ca and Mg were determined by atomic absorption spectrophotometry (Pye Unicam SP 191, Cambridge, UK). The analysis showed that soil in apricot orchard was sandy-loam, moderate in organic matter and total N (1.68% C and 0.14% N), soil pH in KCl 0.01 mol/L was 5.09, and no soluble salt problem in 0–30 cm soil depth. The content of available P and K was 145.2 mg/kg and 174.7 mg/kg, respectively, whereas Ca and Mg were in traces (referring to the amount of phosphorus and potassium).

**Mineral analysis**. Leaf macronutrients were determined in 2004 and 2005. Leaf samples were collected from the middle part of bearing shoots of the trees in five blocks, i.e. three replications of each graft combination. Leaf samples for analysis were collected at monthly intervals, from mid-May to mid-September, i.e. at 60, 90, 120, 150, and 180 DAFB, carefully rinsed with deionized water and, after recording their area, oven dried, weighed, ground to pass a 0.5 mm mesh and analyzed for macronutrient content according to the guidelines of the Association of Official Analytical Chemists (AOAC 1990). The N was determined by Kjeldahl analysis; P was analyzed spectrophotometrically by the phospho-vanadate colorimetric method (Hewlett Packard 8452A, Ontario, Canada); K was determined by flame photometry (Corning 405, Halstead, UK), and Ca and Mg by atomic absorption spectroscopy (Pye Unicam SP 191, Cambridge, UK). Data are given as % of DW.

**DOP index**. The DOP index was estimated for the diagnosis of the leaf mineral status of the trees (Montañés et al. 1991). The DOP index was calculated from the leaf analysis at 120 DAFB by the following mathematical expression:

$$DOP = \frac{C \times 100}{C_{ref}} - 100$$

where: C is the nutrient content in the sample to be studied, and $C_{ref}$ is the major nutrient content considered as optimum, both values given on a dry matter basis. The $C_{ref}$ was taken from optimum values, proposed by Leece and van den Ende (1975) for macronutrients. The ΣDOP is obtained by adding the values of DOP index irrespective of sign. The larger the ΣDOP, the greater is the intensity of imbalances among nutrients.

**Data analysis**. All data are mean values from two years. Using the SPSS software (12.0), the significant differences between means were determined by *LSD* at $P \leq 0.05$. The figures on the dynamics of macronutrient content in apricot leaf are performed by the Microsoft Excel software (Microsoft Corporation, Roselle, IL).

## RESULTS AND DISCUSSION

**Seasonal changes of leaf macronutrients**. The seasonal changes in the leaf mineral composition of Vera apricot cultivar are shown in Figure 1a, e. The leaf N was the highest at 60 DAFB and decreased to 180 DAFB (Figure 1a); the P content decreased from 60 to 90 DAFB and increased from 120 to 180 DAFB (Figure 1b); the K on some groups of interstocks decreased from 60 to 90 DAFB, increased from 120 to 150 DAFB, and decreased at 180 DAFB. With other groups, K increased from 60 to 150 DAFB and decreased in 180 DAFB (Figure 1c); the Ca and Mg increased from 60 to 180 DAFB (Figures 1d, e).

Seasonal changes of apricot leaf macronutrients affected by interstocks. The highest leaf N during

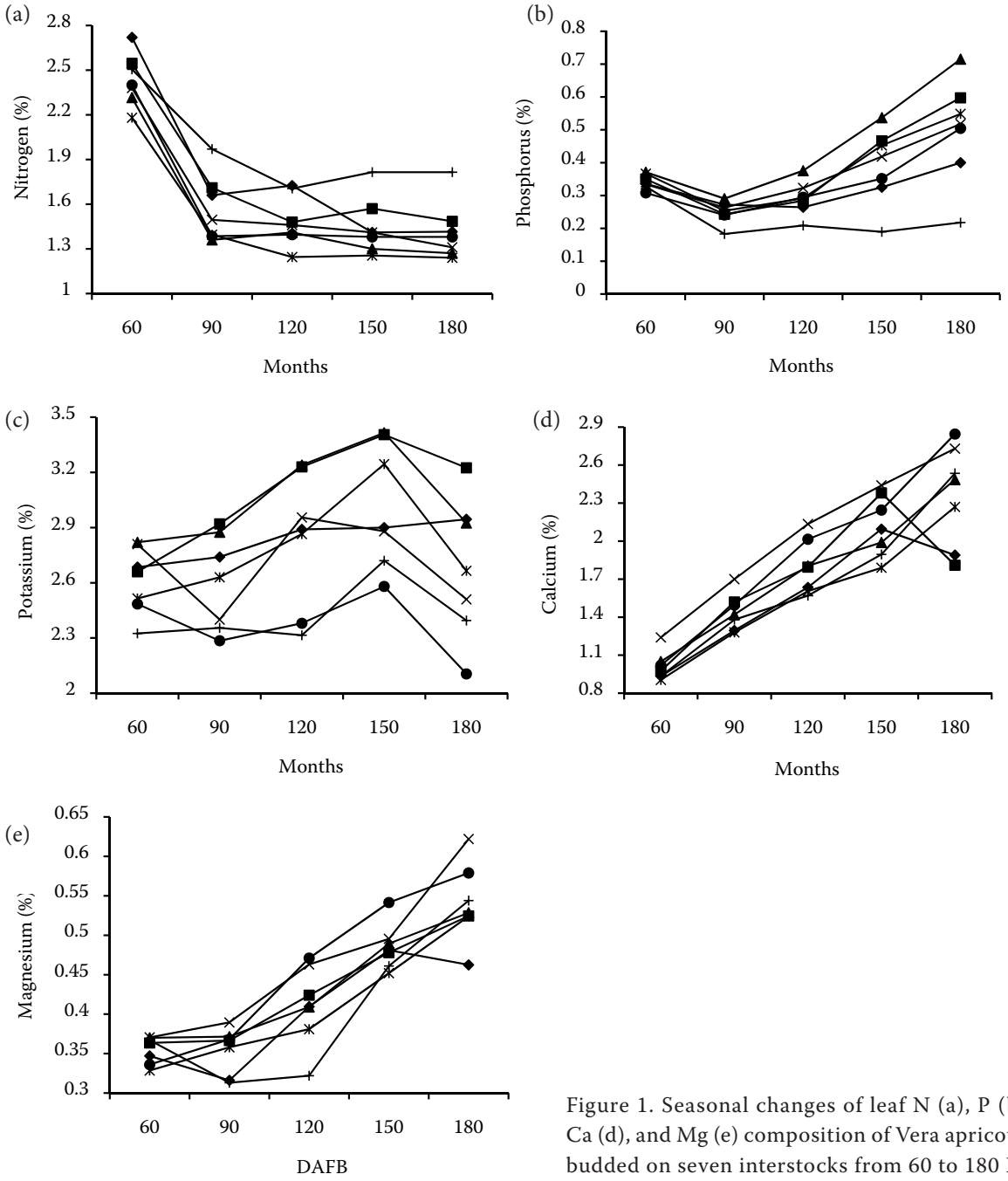


Figure 1. Seasonal changes of leaf N (a), P (b), K (c), Ca (d), and Mg (e) composition of Vera apricot cultivar budded on seven interstocks from 60 to 180 DAFB

growing season was on Kapavac, P on Stanley, K on Dragacevka, and Ca and Mg on Kolenstockczwetsche, while the lowest leaf N and Ca were on Wangenheim, P and Mg on Kapavac, and K on Pozegaca.

For N, leaf content was the highest at the beginning of the growing season, decreasing with leaf growth and during leaf aging (Covelo and Gallardo 2002). According to Chapin and Kedrowski (1983), leaf N decreased during leaf development (by the dilution effect caused by the addition of structural material into leaves) and during senescence, due to the hydrolysis and retranslocation of breakdown products. Leece and van den Ende (1975) stated that leaf N in apricot was not reduced in mid-summer. Our results are in agreement with Leece and van den Ende (1975) for all interstocks, except Belosljiva, where the reduction of N in this period was very intense. It was found that the most suitable period to determine the nutritional state of the apricot tree by means of foliar diagnosis was 120 DAFB (Sánchez-Alonso and Lachica 1987, Lucena 1997).

In contrast, leaf P, Ca, and Mg was the highest at the end of the growing season on all interstocks, except P on Kapavac, which was the highest at the onset of the vegetative cycle (Figures 1b, d, e). Regina et al. (2001) reported that vegetative cycle of deciduous tree leaves is subject to three stages of development: rapid growth, maturation

and senescence. However, during the first period, relative content of P, Ca, and Mg were the smallest, then increased by the end of the vegetative cycle. Similar data reported Leece and van den Ende (1975) for leaf P in apricot, which is associated with the physiological role of P in fruit trees. Since the leaf P on all interstocks had increasing trend during season, except Kapavac (Figure 1b), differences in comparison to previous works can be attributed to their high P uptake capacity and high content of P in soil (Rosati et al. 1997, Liferdi et al. 2008).

At the onset of vegetative cycle (60–90 DAFB), leaf K was slowly changing, to the period of intensive accumulation reaching a maximum value at 150 DAFB on all interstocks, except on Belosljiva, where the increase was moderate and balanced (Figure 1c). Since then, its content is sharply decreased by the end of measurement, which is in accordance with previous study (Bojic and Paunovic 1988). Leece and van den Ende (1975) suggested that the trend of K in the last part of vegetation is physiologically unexpected and difficult to explain. Sánchez-Alonso and Lachica (1987) stated that in plum leaf the tendency of K was not clearly defined.

The leaf Ca considered to be an immobile macronutrient increased until leaf senescence on all interstocks (Figure 1d). The leaf Mg also increased during vegetative cycle on all interstocks (Figure 1e). The dynamics of leaf Ca on Dragacevka and Belosljiva were similar, but leaf Mg trends was in contrast to the dynamics previously described by Leece and van den Ende (1975). The differences between our results and those of above authors could be due to the different ecological conditions, rootstock and cultivars studied. However, similar data for dynamics of Ca and Mg content in apricot leaves reported Bojic and Paunovic (1988) under Serbian conditions. In general, the seasonal variations of apricot macronutrients in leaves were generally minimum starting 20 days before harvest and lasted until harvest or 120 DAFB (Güleryüz et al. 1996). This term was found the best time in order to collect leaf samples.

**Evaluation of leaf macronutrients at 120 DAFB.** Leaf macronutrients content at 120 DAFB significantly varied year by year (Table 1). Leaf N was higher in 2005, while leaf P, K, Ca and Mg were higher in 2004 on all interstocks. Nutrient levels of Vera apricot leaves appeared to be influenced by interstocks. Significant differences were observed among interstocks for N, P, Ca and Mg in both years, except K.

Leaf N was higher on Kapavac in both years, whereas it was the lowest on Wangenheim. The leaf P was higher on Stanley, and lower on Belosljiva and Kapavac. The highest leaf K was shown on Stanley and Dragacevka, and the lowest on Kapavac in both years, although differences were insignificant (Table 1). Leaf Ca was higher on Kolenstockczwetsche and lower on Wangenheim and Kapavac in 2004. In 2005, leaf Ca was higher on Pozegaca and lower on Kapavac. The leaf Mg was higher on Pozegaca and Kolenstockczwetsche and lower on Kapavac in 2004. In 2005, the lowest leaf Mg was shown on Wangenheim, and the highest on Kolenstockczwetsche and Pozegaca (Table 1). Generally, the highest leaf N was on Kapavac, and the lowest on Wangenheim. The highest leaf P and K was on Stanley. On the other hand, the lowest leaf P, K, Ca and Mg were shown on Kapavac. Some authors suggested that leaf macronutrients content affected by vigour of rootstocks and/or interstocks. For example, Rosati et al. (1997) indicated that apricot leaf

Table 1. Leaf macronutrient contents at 120 DAFB in Vera apricot cultivar on seven interstocks in 2004 and 2005

| Interstock | Nitrogen (N) | | Phosphorus (P) | | Potassium (K) | | Calcium (Ca) | | Magnesium (Mg) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 |
| Belosljiva | 1.61 ± 0.18$^{b}$ | 1.76 ± 0.07$^{b}$ | 0.27 ± 0.09$^{e}$ | 0.25 ± 0.03$^{e}$ | 2.70 ± 0.28$^{a}$ | 3.00 ± 0.23$^{a}$ | 1.78 ± 0.21$^{d}$ | 1.41 ± 0.09$^{g}$ | 0.42 ± 0.01$^{e}$ | 0.39 ± 0.03$^{c}$ |
| Dragacevka | 1.60 ± 0.12$^{c}$ | 1.40 ± 0.24$^{d}$ | 0.30 ± 0.07$^{d}$ | 0.26 ± 0.06$^{d}$ | 3.24 ± 0.29$^{a}$ | 3.12 ± 0.52$^{a}$ | 1.89 ± 0.09$^{c}$ | 1.68 ± 0.16$^{d}$ | 0.43 ± 0.02$^{d}$ | 0.41 ± 0.04$^{b}$ |
| Stanley | 1.39 ± 0.11$^{f}$ | 1.47 ± 0.04$^{c}$ | 0.41 ± 0.03$^{a}$ | 0.33 ± 0.07$^{a}$ | 3.30 ± 0.08$^{a}$ | 3.12 ± 0.34$^{a}$ | 1.72 ± 0.16$^{e}$ | 1.82 ± 0.22$^{c}$ | 0.44 ± 0.06$^{c}$ | 0.38 ± 0.12$^{d}$ |
| Kolenstockczwetsche | 1.42 ± 0.13$^{d}$ | 1.48 ± 0.28$^{c}$ | 0.34 ± 0.09$^{b}$ | 0.30 ± 0.11$^{b}$ | 2.63 ± 0.48$^{a}$ | 2.22 ± 0.52$^{a}$ | 2.26 ± 0.33$^{a}$ | 1.93 ± 0.41$^{b}$ | 0.46 ± 0.03$^{b}$ | 0.46 ± 0.07$^{a}$ |
| Wangenheim | 1.25 ± 0.20$^{g}$ | 1.24 ± 0.23$^{e}$ | 0.30 ± 0.01$^{d}$ | 0.26 ± 0.02$^{d}$ | 2.81 ± 0.41$^{a}$ | 2.79 ± 0.20$^{a}$ | 1.61 ± 0.20$^{f}$ | 1.54 ± 0.26$^{e}$ | 0.43 ± 0.01$^{d}$ | 0.33 ± 0.03$^{f}$ |
| Pozegaca | 1.40 ± 0.08$^{e}$ | 1.39 ± 0.12$^{d}$ | 0.32 ± 0.04$^{c}$ | 0.27 ± 0.03$^{c}$ | 2.50 ± 0.29$^{a}$ | 2.20 ± 0.08$^{a}$ | 1.94 ± 0.09$^{b}$ | 2.02 ± 0.21$^{a}$ | 0.48 ± 0.04$^{a}$ | 0.46 ± 0.04$^{a}$ |
| Kapavac | 1.70 ± 0.08$^{a}$ | 1.89 ± 0.45$^{a}$ | 0.19 ± 0.02$^{f}$ | 0.23 ± 0.02$^{f}$ | 2.49 ± 0.27$^{a}$ | 2.07 ± 0.63$^{a}$ | 1.61 ± 0.16$^{f}$ | 1.50 ± 0.29$^{f}$ | 0.32 ± 0.03$^{f}$ | 0.34 ± 0.07$^{e}$ |
| Average | 1.49 ± 0.15$^{B}$ | 1.52 ± 0.23$^{A}$ | 0.30 ± 0.07$^{A}$ | 0.27 ± 0.03$^{B}$ | 2.81 ± 0.33$^{A}$ | 2.64 ± 0.47$^{B}$ | 1.83 ± 0.23$^{A}$ | 1.70 ± 0.23$^{B}$ | 0.42 ± 0.05$^{A}$ | 0.40 ± 0.05$^{B}$ |

The same small letters in columns indicate non-significant differences between means at $P \leq 0.05$ by *LSD* test; the different capital letter in the last row indicate significant differences between years at $P \leq 0.05$ by *LSD* test

on less dwarf rootstocks had lower macronutrient contents, than vigour. On the basis of our results, it can be said that Kapavac had the smallest uptake capacity for all macronutrients, except N. Finally, the macronutrient contents at 120 DAFB in apricot leaf were in order: K > Ca > N > Mg > P, which consigns to very high imbalance among nutrients (Table 1).

**Evaluation of DOP index**. The DOP index was applied to interpret the nutritional state of the apricot tree at 120 DAFB (Montañés et al. 1991). Leaf N, Ca, and Mg was lower than optimum according to Leece and van den Ende (1975) on all interstocks in both years (Table 2); leaf P and K was higher than optimum according to results of above authors. Higher N deficiency was in 2004 than 2005, and Ca and Mg in 2005 than 2004. Higher values of excess were in 2004 than in 2005.

Regarding interstocks, higher N deficiency was registered on Wangenheim, and lower on Kapavac in both years. In our study, soil had a low content of N. It is obvious that CAN fertilizer in amounts of 300 kg/ha or 81 kg/ha N before the onset of vegetative cycle is not sufficient to ensure optimal content of N in the apricot leaf. It is necessary to take into account 75 kg/ha N from 500 kg/ha NPK mineral fertilizer. In addition, soil in our trial is acidic, sandy-loam, clean texture due to the high stakes of sand fractions inclined to big losses soil N (data not shown). From this point, application of N fertilizer in this orchard was inadequate. In addition, unbalanced N fertilization can lead to soil pH decrease (Xie et al. 2011).

The highest Ca deficiency was found on Wangenheim in 2004 and Kapavac in both years, and the lowest on Kolenstockczwetsche in 2004, and Pozegaca in 2005 (Table 2). The highest Mg deficiency was on Kapavac in 2004, and Wangenheim in 2005, and the lowest on Pozegaca in both years and Kolenstockczwetsche in 2005. In the case of Ca, the deficiency of this element is generally induced by antagonism with some element such as Mg (Zarrouk et al. 2005), since Ca counteracts the potential harmful effects of Mg and other divalent cations (Shear 1975). On the other hand, Mg deficiency symptoms developed on trees in the high P treatments (Taylor and Goubran 1975). Our results showed that Ca and Mg content in leaf correlated with their content in soil (Güleryüz et al. 1996).

Leaf P and K were higher than optimum according to Leece and van den Ende (1975) on all interstosck in both years (Table 2). Extremely high excess of leaf P and K in Vera apricot were in Stanley in both years and on Dragacevka for K in 2005. The lowest leaf P and K was on Kapavac in both years and on Pozegaca in 2004. DOP index values for P and K excess are much larger than that reported by Leece and van den Ende (1975). Apricot orchard in our study was on soil with excessively high available P, partially high of K. According to Leece and van den Ende (1975), Myrobalan stock does not readily accumulate K, and probably neither P. Generally, application of NPK fertilizer in our trial was inadequate. In fact, in Vera cultivar, excessive P and K were found on all interstocks. Higher leaf P was also detected in cherry (Jiménez et al. 2004), and it was attributed to excessive P fertilization. Potassium levels in leaves were very high due to the high K content in soil as was also shown in a previous study (Bas and Paydas 1999). In general, Kapavac showed more adequate values of leaf N, P and K, and also more

Table 2. DOP and ΣDOP index determined from leaf macronutrient contents at 120 DAFB in Vera apricot cultivar on seven interstocks in 2004 and 2005

| Interstock | Nitrogen (N)* | | Phosphorus (P) | | Potassium (K) | | Calcium (Ca) | | Magnesium (Mg) | | ΣDOP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 | |
| Belosljiva | −40.37 | −34.81 | +34.50 | +27.50 | +54.28 | +71.43 | −40.67 | −53.00 | −23.82 | −28.18 | 408.56$^{d}$ |
| Dragacevka | −40.74 | −48.15 | +49.50 | +26.20 | +85.14 | +78.28 | −37.00 | −44.00 | −22.73 | −24.54 | 456.28$^{c}$ |
| Stanley | −48.52 | −45.55 | +107.50 | +64.50 | +88.57 | +78.28 | −42.67 | −39.33 | −20.54 | −31.82 | 567.28$^{a}$ |
| Kolenstockczwetsche | −47.41 | −45.18 | +51.00 | +51.00 | +50.28 | +26.86 | −24.67 | −35.67 | −16.91 | −16.37 | 365.35$^{e}$ |
| Wangenheim | −51.85 | −52.96 | +68.00 | +32.00 | +60.57 | +59.43 | −46.33 | −48.67 | −21.09 | −59.27 | 500.17$^{b}$ |
| Pozegaca | −48.15 | −48.52 | +58.50 | +33.00 | +42.86 | +25.71 | −35.33 | −32.67 | −13.27 | −16.37 | 354.38$^{f}$ |
| Kapavac | −37.04 | −30.00 | +14.00 | +14.00 | +42.28 | +18.28 | −46.33 | −50.00 | −42.18 | −38.00 | 332.11$^{g}$ |
| Average | −44.87 | −43.59 | +54.71 | +35.46 | +60.57 | +51.18 | −39.00 | −43.33 | −22.93 | −30.65 | 426.30 |

*leaf composition standards for apricot trees, based on mid-shoot leaves sampled in mid-summer (Leece and van den Ende 1975); – indicate lower content than optimum; + indicate higher content than optimum; the different small letters in the last column indicate significant differences between values of ΣDOP at $P \leq 0.05$ by *LSD* test

adequate values of leaf Ca and Mg on Pozegaca than others interstocks (Table 2).

Significant differences were observed among interstocks for ΣDOP index (Table 2). The highest ΣDOP index values were on Stanley and Wangenheim, and the lowest on Pozegaca and Kapavac. According to ΣDOP index, Stanley and Wangenheim interstocks showed a wider imbalance in nutritional values, whereas Kapavac showed lower intensity of imbalances among nutrients.

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