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Influence of foliar-applied phosphorus and potassium on photosynthesis and transpiration of 'Golden Delicious' apple leaves (*Malus domestica* Borkh.)

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ABSTRACT

The influence of foliar-applied phosphorus (P) and potassium (K) on leaf photosynthesis, transpiration and water use efficiency during the season was studied in *Malus domestica* 'Golden Delicious'. The research was carried out on 14-year-old trees on M9 rootstocks. Trees were either sprayed with PK (Hascon M 10 AD), P (Radicon) or K fertiliser (Krad) or left unsprayed (control). PK spraying improved leaf potassium content and postponed the seasonal decrease in leaf potassium concentration. In other treatments, on the other hand, fertilizers were less effective in terms of leaf nutrient concentration enhancement. In general P, and to a lesser extent PK, spraying resulted in reduced leaf photosynthesis and transpiration to the K and control treatments. High leaf photosynthetic and transpiration rates were measured in the control. Trees sprayed with PK showed the highest water use efficiency during the summer period, which could be a benefit in response to water stress, frequently experienced under given climate.

Key words. foliar nutrition, photosynthesis, transpiration, water-use efficiency, phosphorus, potassium.

IZVLEČEK

VPLIV FOLIARNO NANEŠENEGA FOSFORJA IN KALIJA NA FOTOSINTEZO IN TRANSPIRACIJO LISTOV JABLANE (*Malus domestica* Borkh.) 'ZLATI DELIŠES'

Proučevali smo vpliv foliarno dodanega fosforja (P) in kalija (K) na fotosintezo, transpiracijo in učinkovitost izrabe vode listov jablane (*Malus domestica* Borkh.) 'Zlati delišes'. Poskus je bil zasnovan na 14 let starih drevesih cepljenih na podlago M9. Drevesa smo poškropili s PK (Hascon M 10 AD), P (Radicon), K gnojilom (Krad) in jih primerjali z neškropljenimi drevesi (kontrola). Škropljenje s PK je vplivalo predvsem na večjo vsebnost kalija v listih ter zmanjšalo sezonski padec v vsebnosti tega elementa. Druga obravnavanja so se izkazala kot

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manj učinkovita z vidika povečanja vsebnosti elementov v listih. V primerjavi s K škropljenimi drevesi in kontrolnimi drevesi, je škropljenje s P in nekoliko manj s PK zmanjšalo fotosintezo in transpiracijo listov. Drevesa škropljena s PK so kazala v poletnem času največjo vrednost parametra učinkovitosti izrabe vode, kar bi lahko bilo pomembno z vidika zmanjševanja sušnega stresa, s katerim se pogosto srečamo v naših krajih v tem obdobju.

Ključne besede: foliarna prehrana, fotosinteza, transpiracija, učinkovitost izrabe vode, fosfor, kalij

1 INTRODUCTION

Plant nutrients are taken up both by roots and by upper plant parts (Swietlik and Faust, 1984; Mengel, 2002). For apple trees characterized by high yields nutrient uptake by the roots may be inadequate to meet nutrient demand. This can result from low availability of nutrients in the soil, fixations of potassium ions (Mengel, 2002), lack of water during the summer and concomitant slower diffusion rates of nutrients (Weinbaum et al., 2002), decreased root activity reflecting weaker competition ability for carbohydrates in the fruiting stage (Weinbaum et al., 1994; Marchner, 1995), and from other factors. In addition, fruit trees are, as a rule, deep rooting, which limits the efficiency of fertilizers applied to the soil surface (Mengel and Kirkby, 2001). In several cases foliar uptake of nutrients could be favorable in terms of predictability and efficiency as showed for potassium (Southwick et al., 1996). Foliar fertilization can therefore be a complementary measure taken to provide nutrients during a critical phase of restricted nutrient supply.

In apple, nutrient deficiencies can develop especially in the second half of the growing season in the phase of intensive fruit growth and maturation. This mostly coincides with the greatest likelihood of soil moisture deficit and slowest diffusion rates for nutrients (Weinbaum, 2002). In order to avoid deficiencies, to control growth and to improve quality and storability of apple fruits (Conway et al*.,* 2002; Štampar et al., 1999; Veberič et al., 2002b), foliar nutrition has been used as an important agro-technical measure in last years. Beneficial effects of foliar fertilisers measured by yield quantity and quality could be confirmed by these applications. At the same time it was revealed, however, that the tree response to foliar application of nutrients may be inconsistent (Weinbaum et al., 2002) and that the efficiency of foliar applied nutrients and their utilization is strongly depended on the demand of a tree in the given phenological state and that is nutrient specific. In general, relatively little is known on the basic processes such as mechanisms of nutrient uptake by the leaves, the fate of the nutrients applied and the influence of application on different physiological processes in leaves and fruits (Schlegel and Schönher, 2002; Weinbaum, 1988). In this context nitrogen and calcium were the most investigated as the key elements controlling growth and influencing fruit quality (Klein, 2002; Yuri et al., 2002). On the other hand, far less is known on other nutrients that are already used in foliar sprays in apple production (phosphorus, potassium, boron, zinc (see Faust, 1989; Zude et al., 1997; Štampar et al., 1999; Štampar, 2000).

Therefore, the aim of our study was to estimate the possible effect of the foliar applied phosphorus and potassium on leaf photosynthesis and transpiration in apple *Malus domestica* 'Golden Delicious'. This was continued research work on interaction between foliar-applied nutrients and their influence on selected parameters (Veberič et al., 2002a; Veberič et al., 2002b).

2 MATERIALS AND METHODS

The measurements were carried out in year 2002 on 14-year-old ‘Golden Delicious’ apple trees on M9 rootstock, grown in the experimental orchard of the University of Ljubljana, central Slovenia. The average yield capacity of trees was between 0.83 to 1.11 kg/cm^2 of trunk and didn't significantly differ between treatments. The trees had not been soil fertilized for 2 years prior the start of the experiment. Soil analysis indicated that phosphorus was in the normal range (41 ppm) but potassium was slightly deficient (169 ppm).

The treatments encompassed sprayed trees with phosphorus (P) – Radicon P30 (Greehnhas, 30 % P_2O_5 w/w) in concentration 2,5 l ha^{-1} water, potassium (K) – K-rad (Greenhas, 30 % K_2O in carboxylate and carbonate form) in concentration 2,5 l ha^{-1} water, potassium and phosphorus (PK) – Hascon 10 AD (Greenhas, 15 % P_2O_5 w/w, 20 % K_2O w/w, in the form of bi-potassium phosphate) in concentration 5 l ha^{-1} water and control (CON) – non-sprayed trees. Each treatment involved four trees (4 x 4). The fertilizers were added to water and sprayed in the evening time. No pesticides or other additives were added to the solution. Foliar fertilisers were applied 3 times in the growing season (22.05., 21.06., 17.09.). The dates in days after full bloom (DAFB) for foliar fertilizer application, gas exchange measurement and sampling for the nutrients foliar analysis are presented in Table 1. The commercial harvest date in 2002 was 150 DAFB, however the fruits remained on the tree until the end of the experiment to exclude the effect of lack of sinks for carbohydrates.

Table 1. Dates (also expressed as DAFB = days after full bloom) of foliar fertiliser application, gas exchange measurement and sampling of leaves for estimation of foliar nutrient content.

Fertilization			Gas-exchange measurements			Sampling for nutrient analyses		
1st	22 May	32 DAFB	**1st**	15 May	25 DAFB	**1st**	15 May	25 DAFB
			2nd	30 May	40 DAFB			
2nd	21 June	52 DAFB	**3rd**	20 June	61 DAFB	**2nd**	20 June	61 DAFB
			4th	27 June	68 DAFB			
			5th	02 July	73 DAFB			
			6th	31 July	102 DAFB			
3rd	17 Sept.	150 DAFB	**7th**	30 Aug.	132 DAFB			
			8th	18 Sept.	151 DAFB	**3rd**	18 Sept.	151 DAFB
			9th	20 Sept.	153 DAFB			
			10th	28 Sept.	161 DAFB	**4th**	28 Sept.	161 DAFB
			11th	01 Oct.	164 DAFB			
			12th	15 Oct.	178 DAFB	**5th**	15 Oct.	178 DAFB

The photosynthetic activity and transpiration of the leaves were measured with a portable measuring system Li-6400 (LICOR). Measurements were taken at PFD of 1000 μmol m^{-2} s^{-1} and at 350 ppm CO_2 concentration from 10 a.m till 2 p.m.. Also temperature and air humidity were controlled in the measuring chamber. The conditions in the measuring chamber were the same for all measured leaves. The measurements were performed on spur leaves adjacent to a single fruit so that leaf photosynthesis was stimulated by fruit sink demand for carbohydrates. Leaf was marked and the same leaf was used for gas exchange measurements during the season. The measurements were performed 12 times from the middle of May trough the middle of October (Table 1). Photosynthetic activity (A) of leaves was expressed in μmol CO_2 m^{-2} s^{-1}, transpiration (E) in mmol H_2O m^{-2} s^{-1}. Water use efficiency was calculated as A/E and expressed mmol/mol.

During the experiment samples for foliar analysis were taken. Dates of sampling during the season coincided with the 1st, 3rd, 8th, 10th and 12th measurement of photosynthesis. One sample per tree was composed out of 10 mature leaves sampled from different types of one-year shoots. Before drying, the leaves were washed with distillate water to remove all residues of the applied fertilisers or other pesticides. Plant samples were dried at 40 ^{0}C to a constant weight. The samples were ground to powder. For analysis 1g of sample was taken. The samples were analysed according to method prescribed by ISO 6869:2000 for potassium and ISO 6491:1998 for phosphorus.

Results were statistically analysed by the Statgraphics plus 4.0 software (Manugistics, USA), using the one-way analysis of variance (ANOVA). Differences between treatments were estimated with Duncan’s multiple range test (α <0.05).

3 RESULTS

3.1 Leaf potassium and phosphorus concentrations

Before the first application of fertiliser there were no differences in leaf potassium concentrations in trees that were later subjected to different treatments (Fig. 1). The values were on the lower end of the optimal range for apple (Bergmann, 1992). During the season the amount of potassium in leaves decreased irrespective of the treatment. All values were in the deficiency range, reaching 30 to 50% of the critical potassium concentration. Comparing the last two sampling dates (end of September and middle of October), indicates that no further decrease in leaf potassium concentration occurred in the late season. Fertilisation with PK fertiliser significantly increased leaf potassium content. The most pronounced effect was observed at the second sampling when potassium concentration was one-fold higher in PK treated plants compared to the non-sprayed trees and K-treatment trees, remaining at the level of mid-May concentration. Surprisingly, potassium fertiliser achieved no effect, in terms of enhanced leaf potassium content.

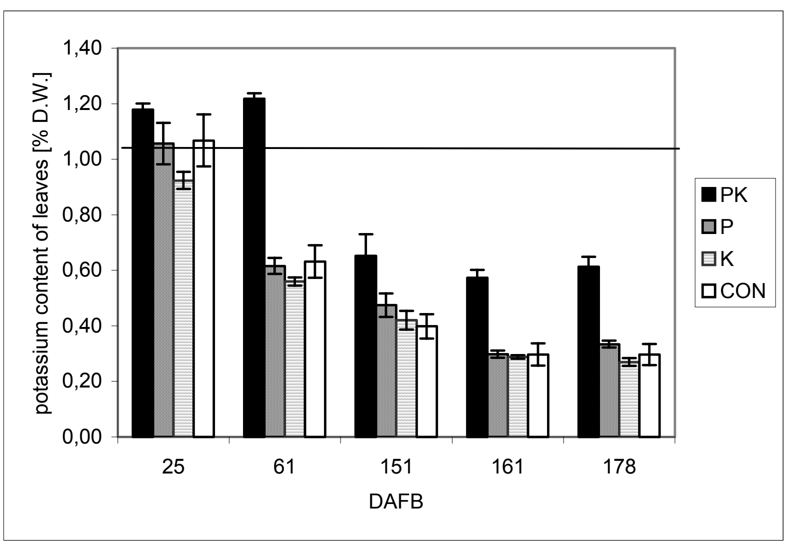

Fig. 1 The leaf potassium content in % of dry weight for different treatments. Bars present average values for the treatments with standard errors. Horizontal line presents the critical content for potassium (according to Bergmann, 1992).

The phosphorus content did not significantly differ between treatments for all sampling dates (Fig. 2). However a tendency for higher content was seen in the samples from the PK and P treatment. At the first sampling the leaf phosphorus concentration was in the optimal range in all trees. Towards the end of the season a decrease occurred, similar to, but less drastic than, in potassium. In September and especially at the last sampling in the middle of October, the leaf phosphorus content was lower than the critical level. Results revealed that deficiency levels were first reached in non-fertilised trees and in trees fertilised with potassium fertiliser (K-treatment).

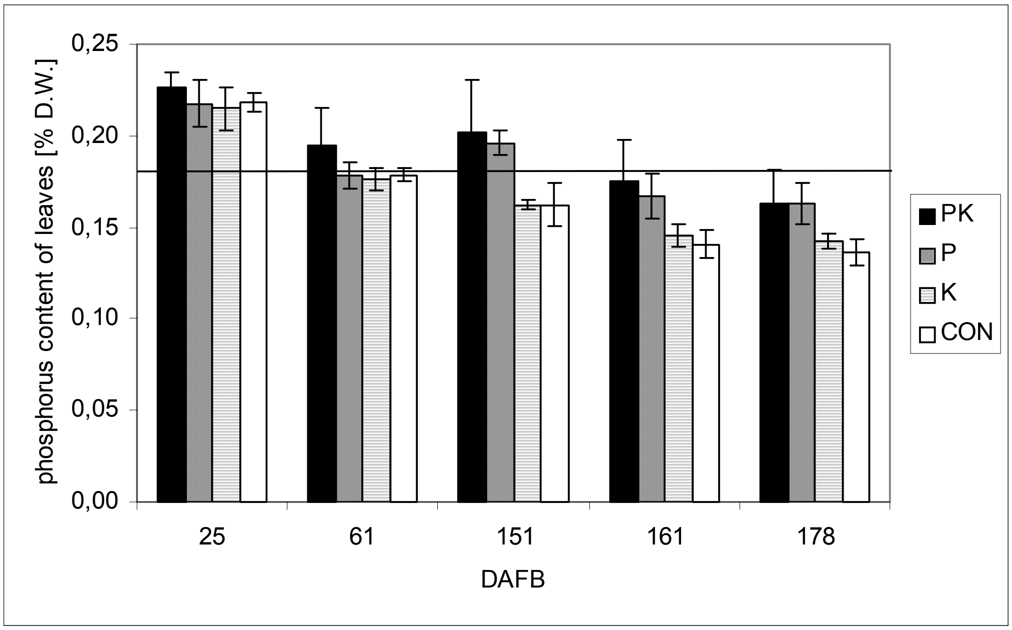

Fig. 2. The leaf phosphorus content in % of dry weight for different treatments. Bars present average values for the treatments with standard errors. Horizontal line presents the critical content for phosphorus (according to Bergmann, 1992).

3.2 Photosynthesis, transpiration and water-use efficiency

The measurement of leaf photosynthesis and transpiration before first application of fertilisers showed no significant differences among selected trees, indicating the equation of the source material.

The photosynthetic activity of leaves was lower in P- and PK-treated trees when compared control trees. Only in 68 and 161 DAFB the PK treatment exhibited higher photosynthetic rates compared to control. In general, the lowest rates in photosynthesis were achieved in P-treated trees (Table 2, Figure 3). This was most pronounced in the 3rd, 5th and 11th measurement (61, 73 and 164 DAFB). The highest rates of leaf photosynthesis from 73 DAFB (begin of July) till end of the season were measured in the control trees (except 10th measurement). Leaves of K-fertilised trees showed a high photosynthetic rate up to 132 DAFB and in the end of the season as well. In all treatments a similar seasonal pattern could be observed. The leaf photosynthesis increased till the end of July (102 DAFB) and decreased from the

August till beginning of October (161 DAFB) showing clear seasonal pattern (see also Veberič et al., 2002; Terhoeven-Urselmans and Blanke, 1999).

Table 2. Photosynthetic activity of apple leaves at 350 ppm CO_2 at different dates (expressed in DAFB = days after full bloom) in year 2002. Data are the mean of each treatment with standard error. Values in a horizontal row followed by a different letter are significantly different at $\alpha<0.05$ by Duncan's multiple range test.

Measurement / (DAFB)		**Photosynthesis [µmol CO_2 m^{-2} s^{-1}]**			
		PK	**P**	**K**	**CON**
1st	25 DAFB	15.55±0.439	14.33±0.549	14.14±0.551	14.65±0.366
2nd	40 DAFB	13.27±0.920	13.40±0.669	14.40±0.727	14.50±1.056
3rd	61 DAFB	17.98±0.196 **ab**	16.85±0.576 **a**	19.40±0.472 **b**	18.60±0.434 **b**
4th	68 DAFB	17.16±0.418 **b**	15.09±0.731 **a**	17.50±0.497 **b**	15.10±0.481 **a**
5th	73 DAFB	17.63±0.265 **b**	15.66±0.816 **a**	17.88±0.43 **b**	18.06±0.367 **b**
6th	102 DAFB	16.34±0.879 **a**	19.31±0.556 **b**	19.44±0.458 **b**	19.60±0.738 **b**
7th	132 DAFB	15.19±0.927	15.28±1.115	15.15±0.453	15.80±0.903
8th	151 DAFB	13.36±0.997 **a**	14.19±0.783 **a**	14.30±0.910 **a**	17.04±0.639 **b**
9th	153 DAFB	13.64±0.977	12.57±0.699	12.75±0.496	15.58±0.708
10th	161 DAFB	11.47±0.659 **b**	9.44±0.449 **a**	9.13±0.522 **a**	8.87±0.714 **a**
11th	164 DAFB	10.73±0.926 **b**	8.73±0.451 **a**	10.30±0.672 **ab**	11.30±0.691 **b**
12th	178 DAFB	9.75±0.495	9.51±0.719	11.06±0.697	10.99±0.916

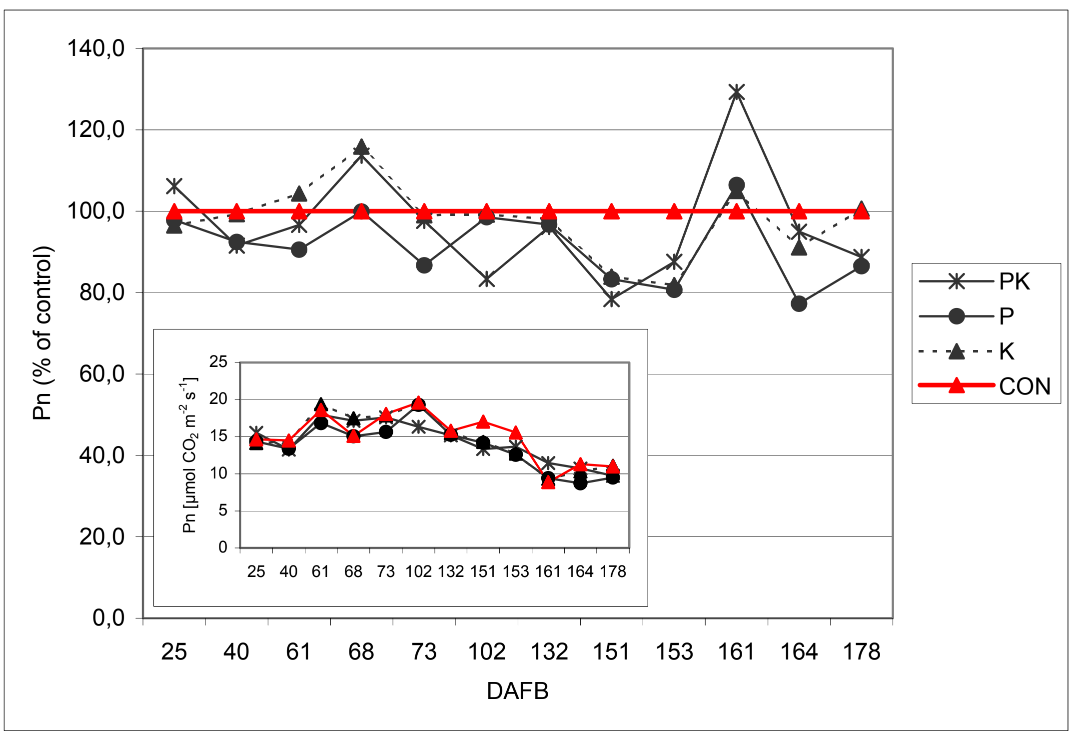

Fig. 3 The photosynthetic activity of apple leaves of different treatments expressed in µmol CO_2 m^{-2} s^{-1} (insert) and in % of the control treatment in different dates in the year 2002.

The leaf transpiration rates (Table 3, Figure 4) showed similar seasonal patterns as the leaf photosynthesis. The highest transpiration rates in all treatments were achieved in the summer and early autumn period. The control treatment maintained high rate of

Table 3. Transpiration of apple leaves at 350 ppm CO_2 at different dates (expressed in DAFB = days after full bloom) in year 2002. Data are the mean of each treatment with standard error. Values in a horizontal row followed by a different letter are significantly different at α<0.05 by Duncan's multiple range test.

Measurement /date		**Transpiration [mmol H_2O m^{-2} s^{-1}]**			
		PK	**P**	**K**	**CON**
1st	25 DAFB	3.97±0.205	3.37±0.275	4.09±0.181	3.57±0.210
2nd	40 DAFB	2.88±0.304	2.85±0.295	3.33±0.315	3.07±0.346
3rd	61 DAFB	5.52±0.089 **a**	5.53±0.075 **a**	6.29±0.135 **b**	6.19±0.137 **b**
4th	68 DAFB	4.14±0.158	3.77±0.125	4.16±0.278	4.11±0.261
5th	73 DAFB	4.38±0.057 **a**	4.44±0.097 **ab**	4.70±0.189 **bc**	4.89±0.124 **c**
6th	102 DAFB	3.75±0.223 **a**	5.11±0.171 **b**	5.46±0.049 **b**	5.51±0.209 **b**
7th	132 DAFB	3.59±0.086 **a**	3.70±0.198 **a**	4.10±0.053 **b**	4.48±0.117 **c**
8th	151 DAFB	3.71±0.281 **a**	4.00±0.116 **ab**	4.27±0.152 **b**	4.51±0.117 **b**
9th	153 DAFB	4.15±0.203	3.93±0.107	4.19±0.089	4.45±0.098
10th	161 DAFB	3.00±0.111	2.74±0.109	2.94±0.047	3.05±0.080
11th	164 DAFB	3.31±0.121 **ab**	3.11±0.151 **a**	3.51±0.148 **b**	3.83±0.133 **c**
12th	178 DAFB	2.96±0.068 **a**	2.89±0.090 **a**	3.35±0.080 **b**	3.20±0.130 **ab**

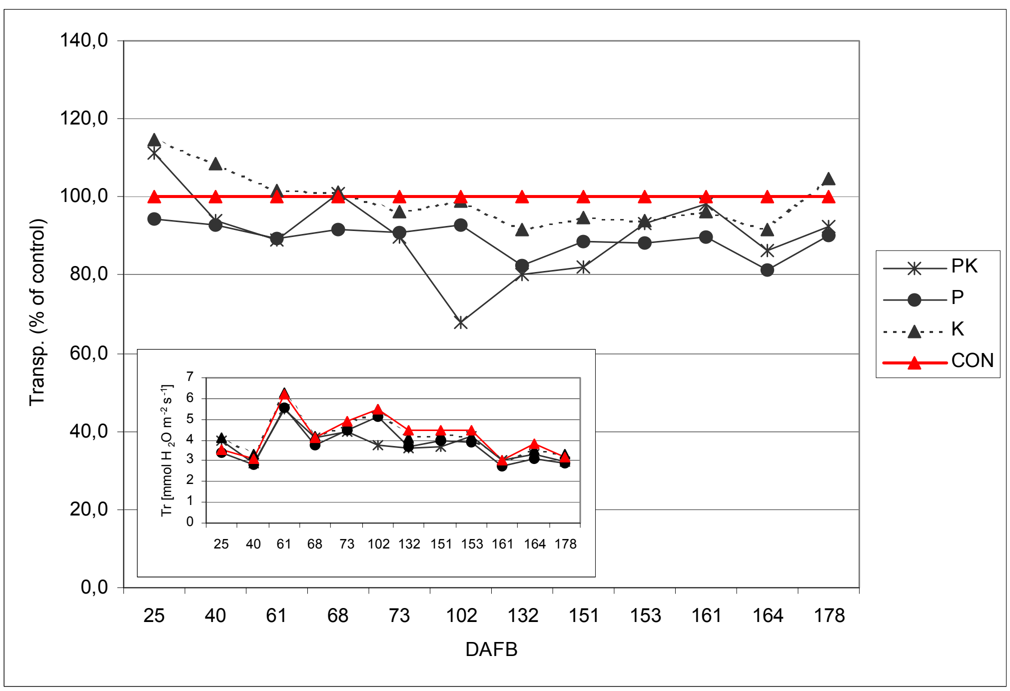

Fig. 4 The transpiration of apple leaves of different treatments expressed in mmol H_2O m^{-2} s^{-1} (insert) and in % of the control treatment in different dates in the year 2002.

leaf transpiration during the summer and autumn period (61 – 178 DAFB). Similar values and high transpiration rates were observed in K-fertilised trees as well. The values for transpiration were the lowest in P and PK treatment, especially in the summer period from the beginning of July (73 DAFB) till middle of September (151 DAFB). Also in the other part of the season the rates in both treatments were lower compared to the control trees.

During the season also a decrease in water-use efficiency in all treatments could be observed (Table 4, Figure 5). The PK treatment showed the highest values in the period from end of June (61 DAFB) till end of August (132 DAFB). It also remained high in the end of the season. A similar pattern of changes in WUE values was observed for PK- and P- treated trees are compared. In the summer period (3rd – 7th measurement) the control treatment had the lowest WUE rates.

Table 4 Water use efficiency of apple leaves at 350 ppm CO_2 at different dates (expressed in DAFB = days after full bloom) in year 2002. Data are the mean of each treatment with standard error. Values in a horizontal row followed by a different letter are significantly different at α<0.05 by Duncan's multiple range test.

Measurement	/DAFB	Water use efficiency [mmol/mol]			
		PK	**P**	**K**	**CON**
1st	25	3.97±0.179 **b**	4.36±0.206 **b**	3.49±0.131 **a**	4.14±0.097 **b**
2nd	40	4.78±0.242	4.86±0.249	4.47±0.211	4.97±0.302
3rd	61	3.26±0.057	3.05±0.118	3.09±0.073	3.00±0.042
4th	68	4.17±0.113	4.03±0.215	4.29±0.189	3.74±0.147
5th	73	4.03±0.036	3.53±0.149	3.83±0.145	3.70±0.066
6th	102	4.38±0.094 **b**	3.79±0.078 **a**	3.56±0.078 **a**	3.56±0.068 **a**
7th	132	4.22±0.195 **c**	4.11±0.145 **bc**	3.70±0.112 **ab**	3.51±0.127 **a**
8th	151	3.63±0.121	3.55±0.151	3.33±0.096	3.78±0.075
9th	153	3.27±0.131	3.19±0.132	3.04±0.076	3.49±0.095
10th	161	3.81±0.149 **c**	3.48±0.169 **bc**	3.11±0.192 **ab**	2.89±0.194 **a**
11th	164	3.22±0.180	2.85±0.199	2.91±0.067	2.94±0.112
12th	178	3.29±0.145	3.30±0.225	3.29±0.158	3.40±0.148

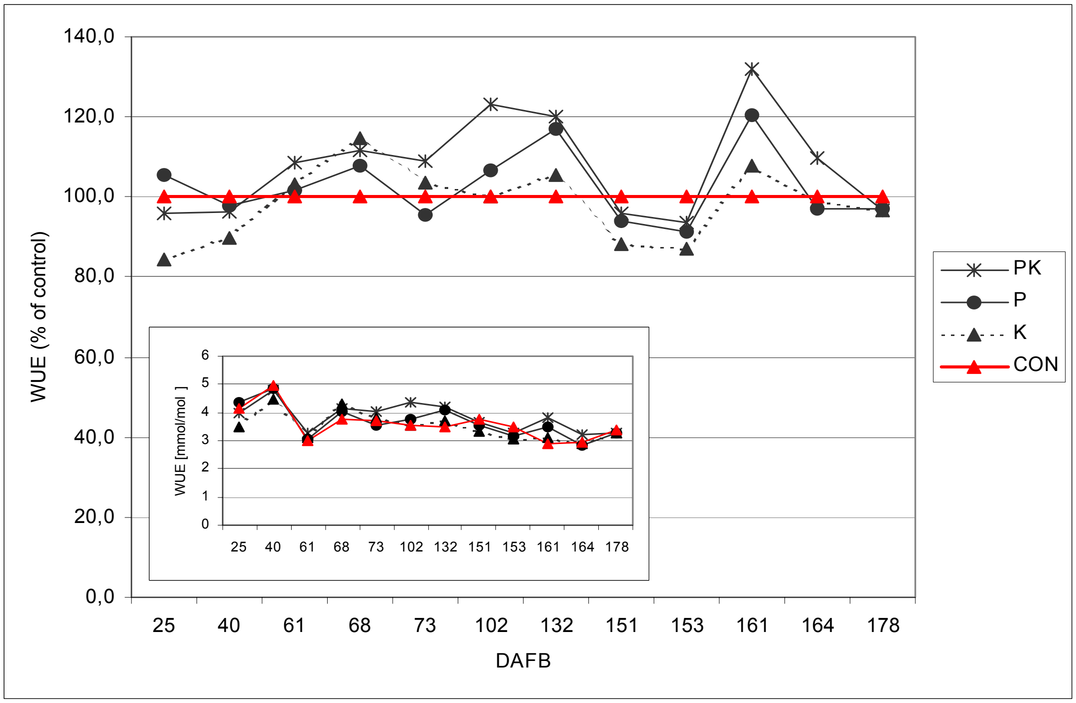

Fig. 5 Water use efficiency of apple leaves of different treatments expressed in mmol/mol (insert) and in % of the control treatment in different dates in the year 2002.

4. DISCUSSION

Foliar analyses revealed a clear seasonal decline of both leaf potassium and phosphorus concentrations. The amount of both nutrients is primarily affected by availability of elements in the soil. It is, however, substantially dependent on degree of cropping and the phase of fruit development (Southwick et al., 1996). Fruits present large sinks for phosphorus and potassium (Buwalda and Lenz, 1992) due to their role in metabolism and translocation of carbohydrates (Marschner, 1995). This can be one of the major reasons also for reductions in leaf concentrations observed in our study. The greatest demand for potassium, for example, is at the ripening period (beginning of autumn) and at that time the lowest levels of potassium were detected in our study. No further decrease of foliar potassium was observed when the ripeness of the fruits was achieved (mid-September) (see also Aichner and Stimpfl, 2002). In the late autumn, in general, a senescence-related decrease in leaf nutrients can be expected (Terhoeven-Urselmans and Blanke, 1999). Tartachnyk and Blanke (2001) reported that an 8 to 11% decline in apple leaf potassium and a 40% decrease in phosphorus could be observed five weeks after the harvest. A similar trend was confirmed for phosphorus in the present study and by our previous research on 'Golden Delicious' (Veberič et al., 2002a), but the same was not true for potassium. No decrease in leaf potassium concentration was observed after September (see also Veberič et al., 2002a).

Foliar analyses revealed that foliar fertilisers applied exhibited relatively low effectiveness on leaf nutrient concentration enhancement. In this context especially the effects of potassium fertiliser (K-treatment) were not noticed. Interestingly limited increase of foliar concentration in response to leaf application is frequently reported for macronutrients and is known also for potassium (Weinbaum, 1988) where it is suggested that several sprays per season are needed to achieve better results. On the other hand there are clear indices from our experiment that PK spraying could significantly improve leaf potassium status and postpone the decrease in leaf K concentration.

On the basis of our experiment it cannot be elucidated whether low responsiveness of leaf nutrient level to spraying is a result of limited uptake into the leaves or more a results of fast translocation and utilization rate reflecting high nutrient demand. It is known that leaf uptake is affected by external factors, such as mineral nutrient concentration, application rate, ion valency, temperature, … and internal factors, such as metabolic activity, leaf age, properties of membrane and cuticle, etc. (Chamel, 1988; Weinbaum, 1988). It was, for example, shown that the rate of phosphorus uptake by the barley leaves was twice as high in P-deficient plants as in control plants well supplied with phosphorus via the roots. In addition, in the deficient plants, much more phosphorus was translocated from the leaves (Clarkson and Scattergood, 1982). In our study both phosphorus and potassium were in deficiency in the second half of the season and this could substantially influence uptake, translocation and utilization patterns.

Despite of the fact that only minor changes of foliar phosphorus and potassium concentration (except PK-treatment) after spraying were found, differences in photosynthesis and transpiration can be observed between differently treated trees. In general, higher photosynthetic rates were measured in control trees when compared to P- and PK-treated. A decrease of photosynthesis in response to PK application was found also in our previous studies (Veberič et al., 2002a; Veberič et al., 2002b) and Swietlik et al*,* (1982a) reported reduced apple leaf photosynthesis on the day of the application of foliar fertilizer (complete nutrient solution) and it seems that decrease in photosynthesis due to nutrient sprays is not unique (Swietlik and Faust, 1984). Its nature and dynamics however is poorly understood.

Foliar analyses revealed that the phosphorus deprivation is not severe in our experiment. A positive correlation of photosynthesis and phosphorus leaf content is well confirmed and understood (Pieters et al., 2001). It was clearly shown also for fruit trees (DeJong, 1982). On the other hand, it is assumed that, due to the finely tuned homeostasis and turnover of P_i in the cell, photosynthesis is not severely affected when phosphorus deficiency is mild (Rao et al*.,* 1990; Marschner, 1995), which would explain our results.

It is interesting that no difference in leaf photosynthesis was found at mid-June measurement when there was a big difference in leaf potassium concentration between the treatments (substantially higher potassium concentration in the leaves of PK treated trees). Recent study showed that leaf potassium concentrations similar to those that were measured in our experiment in the second half of the season (less than 0.5-0.6%) appeared to limit leaf CO_2 exchange rate in almond trees (Basile et al*.,* 2003). Beside chloroplast effects (Marschner, 1995) photosynthesis could be affected by potassium also at other levels (enzyme activity, stomatal functioning). Our study revealed that transpiration is lower (especially in the summer period) in trees sprayed with P- and PK- fertilizer when compared to control trees. Since P- and PK- treatments differ in potassium content, the lower transpiration rates to control treatment cannot be simply explained by different stomata response to potassium concentration. In the study by Swietlik et al., (1982b) potassium foliar fertiliser decreased stomatal conductance and photosynthesis in water-stressed apple trees. On the other hand, no effect of fertiliser was observed in non- stressed trees. In this context, findings of our study could also be interesting when the response of 'Golden Delicious' to water-deficit stress is concerned (see results on higher water-use efficiency in the late summer, Table 4). This is also important due to the fact that the frequency and duration of dry periods has increased in recent years, which could limit apple production in our climatic region.

On the basis of the results achieved in our study on 'Golden Delicious' apple trees it can be concluded, that foliar application of fertilisers in P and PK treatment resulted in some increase in the leaf nutrient concentration. However several applications would be needed to improve nutrient status of the leaves. The potassium fertilizer used in this study didn't result in higher potassium concentration in leaves. The applied fertilizers (PK and P) decreased leaf transpiration and to some extend also the leaf photosynthesis, but they increased the water use efficiency in the summer period, what could be beneficial when the water availability is limited. This work is a contribution to further investigations on the impact of foliar nutrients on physiological processes of the apple trees. Also the influence on other processes like enzyme activity, carbohydrate synthesis, and fruit quality parameters should be considered.

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