REMOVAL OF NITROGEN, PHOSPHORUS AND POTASSIUM WITH SUMMER PRUNING OF APPLE TREES

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Abstract

The objective of the research was to study the removal of nitrogen, phosphorus and potassium with summer–pruned branches of apple–trees grown on dwarfing rootstocks under the influence of applied moisture regulation methods. The investigation was done at the Latvia State Institute of Fruit-Growing in Dobele, on the basis of an existing field experiment planted in 1997 with cultivar 'Melba' (rootstock B9) at 1.5 × 4 m trees spacing distances. Three different treatments of soil moisture management was compared: control (without moisture regime regulation), sawdust mulch and fertigation. Inter–row strips were covered by grass vegetation (*Lolium perenne* L. and *Poa pratensis* L., in proportion 1:3). Pruning of apple–trees was done in mid–July. The results of the research showed that the applied soil water regulation treatments (mulch and fertigation) had significant influence ($p<0.05$) on the apple–tree biomass (leaves, one–year and older wood) removed by summer pruning, as well as on the content of dry matter in biomass. The contents of N and K were influenced both by the treatment and age of tree vegetative parts, but the content of P did not differ significantly among treatments or tree parts ($p>0.05$). Removal of N with summer–pruned leaves and branches was 30 kg ha^{-1} N in the mulch treatment and 16 – 17 kg ha^{-1} in control and fertigation treatments ($p<0.05$). Removal of K in the control treatment was 19 kg ha^{-1}, in the mulch treatment 40 kg ha^{-1}, but in the fertigation treatment 27 kg ha^{-1} ($p<0.05$). Removal of P varied from 5.04 to 9.84 kg ha^{-1}, no significant differences were found among treatments ($p>0.05$).

Key words: fertigation, mulch, nutrient removal.

Introduction

Since the end of the 20th century with the rapid development of commercial fruit growing in Latvia, the farmers are introducing more advanced growing technologies for apple (*Malus domestica*. Borh.) production. One of the relatively new method is summer pruning of apple–trees (summer pruning of branches) at the end of June, July, also August. Summer pruning is mostly done for improvement of light conditions inside the tree canopy (Autio and Greene, 1990; Wagenmakers and Callesen, 1995). Low light access decreases the amount of soluble solids and starch in fruits, therefore fruits are smaller, ofted deformed, with too low flesh firmness. Lack of sunlight also has a negative effect on fruit colour, such fruits cannot be sold as dessert quality products. Summer pruning also reduces tree size, as well as the development of harmful organisms (insects, diseases). By pruning of branches the density of the canopy is reduced, so the air humidity inside the canopy decreases. High humidity in combination with high temperature makes optimal environment for the development of pests and diseases (Lakso et al., 2003).

There are additional aspects related to the pruning. Plant nutrients, like nitrogen, phosphorus and potassium, are irreversibly removed from the orchard with the cut–off branches if they are taken off from the area. The above mentioned nutrients, also called main macroelements, because plants need them are in comparatively high amounts, and they are very important for tree development and yield formation. Nitrogen is necessary for many life functions of the tree, such as growth of shooots, setting of buds and fruits, and fruit growth. Nitrogen deficiency for apple–tres results in several negative consequences: the shoots grow weak, leaves become light green or yellowish, which in turn negatively influence the intensity of photosynthesis (Fallahi et al., 2001; Cmelik et al., 2006). Phosphorus requirement for apple–trees are less compared with field crops (Neilsen et al., 2006), but it is essential for the provision of the transfer of plant genetic information. Phosphorus takes part in the plant metabolism, respiration, photosynthesis, facilitates fertilization of the flowers. Lack of phosphorus has negative effect on the growth and development of the plant reproductive organs (seeds), as well as vegetative parts (trunk, leaves). Potassium, on the other side, facilitates the water supply in cells, the accumulation of carbohidrates. The amount of potassium influences also fruit colour, tree winter–hardiness and disease resistance. If there is not enough potassium, brown necrotic spots appear on leaf margins, older leaves can even die, and plants become susceptible to fungal diseases (Nosal et al., 1990).

Novelty of discussed experiement is that introduction of summer tree pruning is a new method for Latvian commercial farms. This method has been introduced based on experience of other countries. There is a lack of information about the loss of nitrogen (N), phosphorus (P) and potassium (K) through removed wood and leaves. Also data about distribution of plant nutrients in differt parts of apple–trees are quite old and go back to the 1960–ties – 1970–ties (Dimza and Gross, 1994). These data are applicabile for trees on vigorous seedling rootstocks with traditional late winter pruning. Researchers in other countries (Bünemann and Struklec, 1980) have come to a conclusion that during the growth season vegetative parts of apple–trees (branches, leaves) contain nutrients in a significantly higher concentration than during dormancy. Therefore lost of nitrogen, phosphorus and potassium might be higher for summer–pruned branches and leaves compared with traditional technology when crown formation was done in early spring. Additionally, more and more of commercial growers are introducing different soil water management methods. In average amount of precipitations in Latvia is adequate for plant water supply, but some periods in summer when water requirement is high there could be some deficit which has negative influence on apple yield and yield quality. Therefore soil moisture regulation technologies: mulching of tree strips, as well as establishing of various irrigation systems, become more popular. Water management may affect not only the nutrient turnover, uptake, fertiliser use efficiency, but also their loss from the rooting zone. The applied soil moisture regulation methods and the removal of nutrients with apple–trees are the basic factors when fertilization planning is performed. Therefore the objective of this study was to assess the amount of nitrogen, phosphorus and potassium removed with plant parts trimmed by summer pruning, in relation withe aplied soil moisture regulation methods – sawdust mulch or fetigation.

Materials and Methods

The investigation was carried out at the Latvia State Institute of Fruit–Growing, Dobele, in 2008. Field trial in three replications was set up on the basis of an orchard planted in 1997, for cultivar 'Melba' on rootstock B9 (planting pattern 1.5 × 4 m). Three kinds of soil water treatments in tree strips were compared: (1) control – no any regulation methods; (2) sawdust mulch and (3) fertigation, e.g., drip irrigation with fertilizer. In the mulching treatment soil surface was covered with 10 – 20 cm layer of sawdust renewed every three years. In the irrigation treatment 'Den' type pipelines with built–in drippers spaced 0.38 cm apart were used. The irrigation provided effective moistening of a 1 m wide zone in sandy loam soil or about 25% of orchard area.

For the lawn sown in the inter–row strips *Lolium perenne* L. and *Poa pratensis* L. in proportion 1:3 were used. The tree strip in the control and drip irrigation treatments were 1 m wide and during the growing season it was maintained free from grasses. The inter–row strips were 3 m wide. The grass during the experiment was mown regularly (5 – 6 times per season). The apple–trees were performed as slender spindle. The average yield was 20 t ha^{-1}. Branches of apple–trees were pruned in mid–July. In July, 2008 the precipitations was below the normal (only 60 mm), but the mean air temperature was close to the average, +18 °C.

Soil of experimental plot was Haplic Luvisol (Hypereutric), sandy loam, interspaced with Cutanic Luvisol, sandy loam. These are typical automorphic soils with relatively good water storage and water supply capacity. Organic matter content in soil – 25 g kg^{-1} (according Tyurin method, wet combustion), soil reaction pH – 6.5 (in 1*M* KCl suspension, potentiometrically). Plant available P was 130.9 mg kg^{-1}, K – 157.7 mg kg^{-1}, and Mg – 102.2 mg kg^{-1} (according Egner – Rheem or DL method).

During the summer pruning (July 12) all the cut branches and leaves were collected and grouped into one–year, two–year or older wood and leaves, weighed, air–dried and chopped. Chemical analyses were done for the above–mentioned vegetative tree parts, determining the total nitrogen (Kjeldahl method, wet digestion), phosphorus – P (colorimetrically) and potassium – K (flame photometerically) concentration in plant material. The removal of nutrients were calculated as kilograms per hectare area (kg ha^{-1}) (Kārkliņš, 1988).

The results of the investigation were analyzed using analysis of variance *ANOVA* test, as well as descriptive statistics *(Descriptic statistic)*. To compare the data from two sample groups Fisher criteriom was used.

Results and Discussion

The applied methods of soil moisture regulation – mulch and fertigation – had significant ($p<0.05$) influence on the content of dry matter in apple–tree vegetative parts removed by summer pruning (Table 1). The lowest content of dry matter was in the fertigation treatment, the highest – in control treatment.

The highest content of dry matter was found for older wood in control and mulch treatments, it was 30 – 40% higher than in one–year wood, and the difference was statistically significant ($p<0.05$). It may be explained by different moisture supply in the above mentioned treatments. Other researchers (Nagy et al., 2006) point out that apple–trees which have higher available soil moisture supply contain less dry matter in biomass. That may indicate that apple–trees grown with fertigation have more favourabale moisture conditions. Yet in that study the total biomass of summer–pruned vegetative parts was significantly higher ($p<0.05$) not in the fertigation, but in the mulch treatment. The biomass from mulched apple–trees amounted up to 3.13 kg, in the fertigation treatment 2.2 kg, but for control plot – only 1.95 kg per tree. Investigations done in Latvia (Rubauskis, 2005) also showed that the increase of biomass is positively influenced by mulching. Leaves on one–year wood contained significantly less dry matter in the fertigation treatment as compared with control, while the mulch treatment did not significantly differ from control. Leaves on two–year wood contained similar amounts of dry matter in all treatments ($p>0.05$).

Table 1

Content of Dry Matter in Apple–tree Vegetative Parts (g kg^{-1})

Tree vegetative parts	Control (n = 9)	Mulch (n = 9)	Fertigation (n = 9)
Leaves on one–year wood	57.3 ± 4.7 ^{b}	53.2 ± 1.6 ^{ab}	49.7 ± 2.2 ^{a}
One–year wood	45.2 ± 6.4 ^{d}	47.2 ± 2.9 ^{c}	44.5 ± 2.8 ^{bc}
Leaves on two–year wood	53.5 ± 5.2 ^{ab}	52.6 ± 1.5 ^{ab}	49.8 ± 2.3 ^{ab}
Two–year wood	69.5 ± 1.5 ^{g}	66.5 ± 1.8 ^{f}	63.3 ± 1.3 ^{e}
Older wood	76.6 ± 1.8 ^{i}	72.6 ± 1.6 ^{h}	69.4 ± 1.7 ^{g}
Average	60.44	58.42	55.3

a, b, c, d, e, f, g, h – significantly different ($p<0.05$).

Dry matter content in the control treatment had comparatively high dispersion of data, especially in leaves of one–year wood (S_x = 4.7) and in leaves of two–year wood (S_x = 5.2), as well as in one–year wood (S_x = 6.4). In the mulch and fertigation treatments data dispersion was 2 times lower. Variation of data possibly is an evidence of different growth conditions of apple–trees. Mulch and fertigation ensured optimal moisture supply to plants, so the moisture content in plants also was more even, while in the control treatment moisture supply tends to be irregular and trees often has lack of water (Evans et al., 1985; Rubauskis, 2005). For the content of dry matter in older wood, differences in data dispersion among treatments were insignificant.

Apple–tree leaves contained 2 times more nitrogen (N) per one dry matter unit than wood (Figure 1), and the difference was significant ($p<0.05$). In the control treatment the leaves contained signifcantly less nitrogen than in mulch and fertigation treatments ($p<0.05$). In one–year, two–year and older wood the content of nitrogen per dry matter unit did not differ significantly among treatments ($p>0.05$).

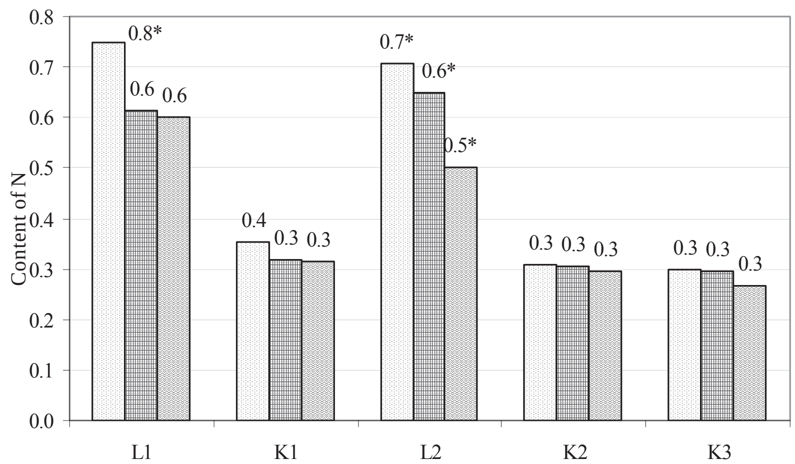

Figure 1. Content of nitrogen (N) in apple–tree parts per unit of dry matter.

– control – mulch – fertigation

* – significantly different ($p < 0.05$)

L1 – leaves on one–year wood; K1 – one–year wood; L2 – leaves on two–year wood; K2 – two–year wood; K3 – older wood.

The results of this experiment do not fully comply with findings of other researchers (Burke and Morris, 1993; Gland, 2006) that in younger plant parts the content of N usualy is higher. Content of N in vegetative parts of apple–trees is the highest during the active growth – in May, June, but in July vegetative growth starts to decrease (Nurzinski et al., 1990). Summer pruning of apple trees was done in July that possibly explains why there were no significant differences between one–year, two–year and older wood. Probably nitrogen in plants has high reutilisation capacity. Depending on plant vegetative part age N uitilization rate cauld be 70 – 80% from total assimilated in leaves (Adamec, 2002). It is possible that in the control treatment (as a result of periodical moisture deficit) the changes of N concentration and the reutilisation process were slower. Nitrogen in plants is found either in the form of NO_3^- (mobile) or NH_4^+ (immobile) ions (Dong et al., 2005). In this study only total N was determined in plant parts. Therefore there is not enough data to explain variation of nitrogen content in apple leaves expecially in relation to it high value in control treatment.

Although results of the study showed tendencies for the content of P in apple–tree wood (Figure 2) to decrease depending on the age of wood, still the differences among treatments, as well as types of vegetative parts were not significant ($p>0.05$). In the fertigation treatment the amount of P found in apple leaves was 3 times higher compared with one–year wood, but difference statistically was not significant due to the high data variability. The content of P in apple–tree vegetative parts starts to decrease already after flowering (Nurzinski et al., 1990). It is possible that during summer pruning when the content of phosphorus in apple tree parts was decreasing rapidly, the turnover of P was influenced also by its reutilisation, which in comparison with other studied elements is lower, 51 – 82% (Adamec, 2002), and this can also explain the insignificance of differences and the high data variation.

Other researchers (Burke and Morris, 1993) also had pointed out that the age of apple–tree vegetative parts does not influence P content in it.

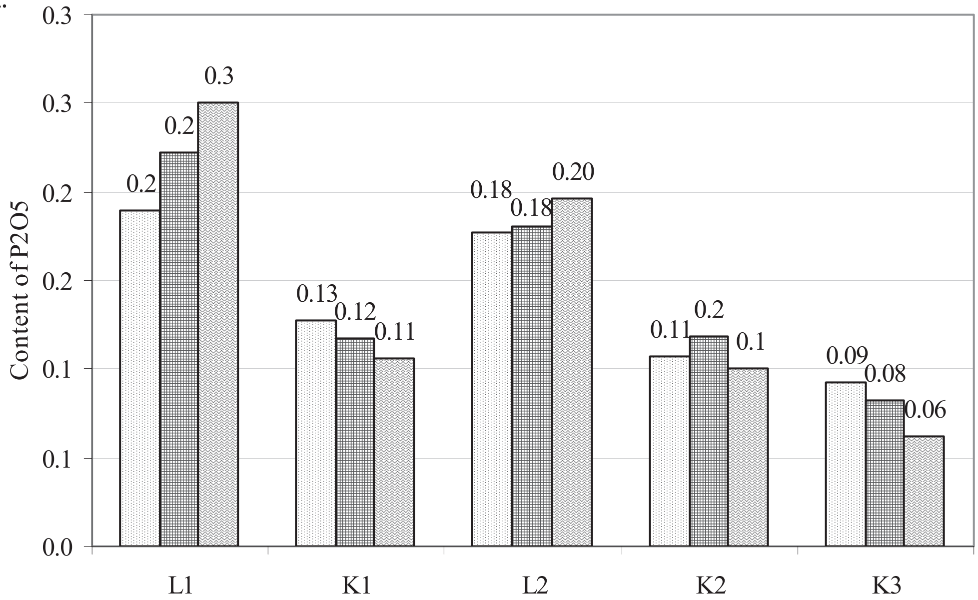

Figure 2. Content of P in apple–tree parts per unit of dry matter.

– control – mulch – fertigation

L1 – leaves on one–year wood; K1 – one–year wood; L2 – leaves on two–year wood

K2 – two–year wood; K3 – older wood.

The K content in dry matter was significantly influenced both by the age of apple–tree vegetative parts and the method of applied soil moisture regulation in tree strips: mulch or fertigation (Figure 3). Leaves of apple–trees contained even 3 – 4 times higher potassium than wood, and one–year wood 2 times higher potassium than two–year and older wood. Our results agree with conclusions made by researchers in other countries that the content of potassium in younger leaves is higher (Burke and Morris, 1993; Aichner, 2002), compared with old leaves and other parts of plant. Although the content of K, similarly as for N, was significantly higher in apple–tree leaves ($p<0.05$), especially leaves of one–year wood, yet the data obtained in our study showed different tendencies compared with nitrogen content (Figure 1). Significantly higher content of K in leaves of one–year wood was found in the fertigation treatment, and a similar tendency was also found for the content of K in other vegetative parts, only the differences among treatments were not statistically significant (p>0.05).

The content of potassium in the vegetative parts of apple–trees increases since the beginning of growth season, reaches its maximum at the beginning of June, then for 10 weeks it remains stable and afterwards begins to decrease (Nurzinski et al., 1990; Aichner, 2002). This may explain the relatively low variation of the results in our experiment. From all the elements analyzed in this experiment, potassium is supposed to be the most mobile, and also with very high reutilization capacity – up to 95 – 99% (Adamec, 2002). Mobility of potassium in soil is facilitated by the amount of water. The more water is available for plants, the faster potassium moves in cells (Malaguti et al., 2006). This may explain the significantly higher content of K in the fertigation treatment.

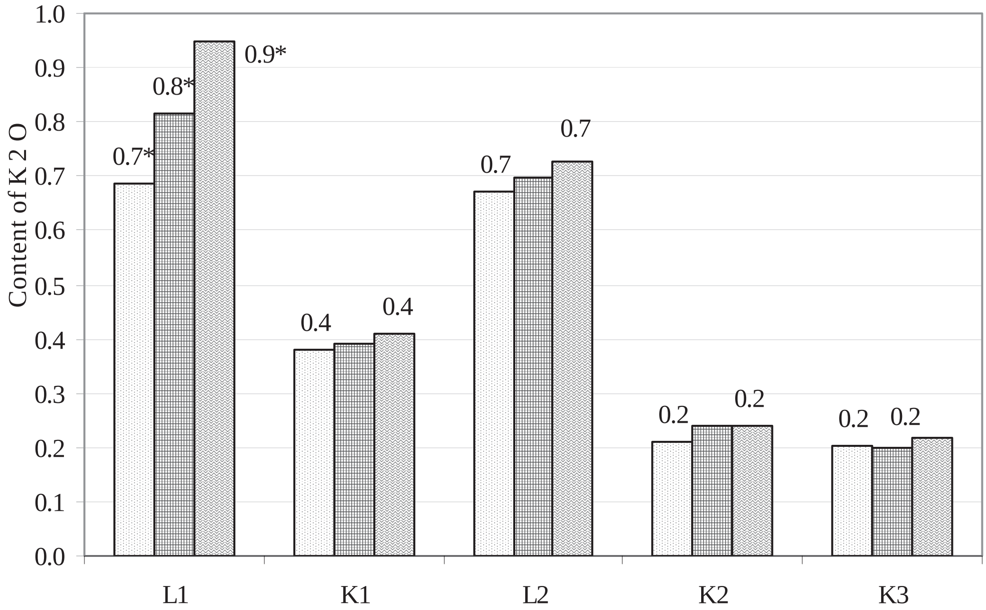

Figure 3. Content of K in apple–tree parts per unit of dry matter.
– control – mulch – fertigation
* – significantly different (p < 0.05)
L1 – leaves on one–year wood; K1 – one–year wood; L2 – leaves on two–year wood
K2 – two–year wood; K3 – older wood

The method of soil moisture regulation significantly influenced (p<0.05) removal of nutrients by summer–pruned vegetative parts (Table 2). In the mulch treatment removal of N was 2 times higher than in fertigation and control plots, removal of potassium was also 2 times higher in the mulch treatment than in the control, while removal of phosphorus did not differ significantly among the treatments (p>0.05). Removal of nitrogen and potassium did not differ significantly in the control and mulch treatments, while removal of phosphorus in these treatments was 3 times lower. In the fertigation treatment removal amounts of all three nutrients differed significantly (p<0.05), the biggest part was potassium (50% from total nutrient removal).

One–year old wood together with leaves composed the biggest part of total nutrient removal. One–year wood and its leaves in the control treatment made up to 63% from the total N removal per ha, but in the mulch and fertigation treatments even 75% from the total N removal. Removal of P and K with the above mentioned tree parts was 67% (control) and 78 – 82% (mulch and fertigation) from the total phosphorus and potassium removal. Sometimes fruit production orchards are used also for obtaining the propagation material. Taking into account that only one–year shoots are cut as graftwood (cutting of grafts is done at the same time as summer pruning), in this case substantial amount of nutrients is removed from the orchard.

Data obtained in our experiment cannot be directly compared with the results obtained by I. Dimza and A. Gross in 1960 – 1970–ties (Dimza and Gross, 1994), as these researchers investigated nutrient removal by tree pruning in the end of winter and most of the trials corresponded with the late-season cultivar `Antonovka`. In the current study the early apple cultivar `Melba` was used, and, according to conclusions of Polish researchers (Zydlik and Pacholak, 2006), nutrient removal from early cultivars is significantly higher. Although the results are not directly comparable, similar tendencies were observed – the largest part from the total nutrient removal was made up by K, removal of N was about 1.5 times lower, but the lowest removal was for P (Dimza and Gross, 1994). The result of our experiment agrees with conclusions of Latvian (Dimza and Gross, 1994) and other researchers (Neilsen et al., 2006) that phosphorus uptake by apple–trees, unlike for other cultivated plants, is lower compared with nitrogen and potassium.

Table 2

Removal of Nutrients through Summer–pruned Branches and Leaves

Nutrients	Treatment	One–year wood leaves	One–year wood	Two–year wood leaves	Two–year wood	Older wood	Total	Nutrient removal, kg ha^{-1} (1666 tree per 1 ha)
	per tree, g							
N	Control	4.61	1.69	2.98	0.44	0.26	9.99	16.64*
	Mulch	10.57	3.07	3.27	0.88	0.52	18.30	30.49*
	Fertigation	5.81	2.25	1.81	0.55	0.18	10.60	17.66*
P	Control	0.64	0.24	0.30	0.10	0.04	1.32	2.20
	Mulch	1.55	0.50	0.33	0.15	0.05	2.60	4.30
	Fertigation	1.22	0.37	0.33	0.11	0.02	2.04	3.40
K	Control	4.96	1.55	2.45	0.36	0.20	9.56	15.92*
	Mulch	12.97	3.20	3.71	0.58	0.22	19.70	32.81*
	Fertigation	8.61	2.49	1.88	0.46	0.11	13.55	22.57*

* – significantly different ($p < 0.05$)

Research results found in publications about the influence of soil water treatments on the content of nutrients in apple–tree vegetative parts are controversial. Some researchers (Evans and Proebsting, 1985; Malaguti et al., 2006) demonstrated that the amount of nutrients in apple leaves increases along with the increase of their moisture content, but researchers from Warsaw University (Pietranek and Jadczuk, 2005) came to the opposite conclusion that fertigation has no influence on the mineral composition of leaves. It is possible that the changes of nutrient content in apple–tree vegetative parts were influenced by weather conditions of the growth season along with THE soil water capacity. This is supported by other study in Poland (Zydlik and Pacholak, 2006), where close correlation was found between air temperature, precipitation and apple leaf mineral composition. Therefore the amount of nutrients in vegetative parts depends also on weather conditions in the specific growth season.

Conclusions

The applied soil moisture regulation methods (mulch and fertigation) had significant influence on the content of dry matter in the vegetative parts of apple–trees ($p<0.05$). The highest content of dry matter (g kg^{-1}) was found in the control plot, but the highest amount of biomass removed by pruning – in the mulch treatment.

The content of N per one unit of dry matter (g kg^{-1}) was influenced by the applied soil moisture treatment. Significantly higher content of N was found in the control plot. Both in one–year and older wood the content of N was lower than in apple leaves ($p<0.05$). The content of P did not depend of the treatment or the age of tree vegetative parts. In the mulch and fertigation treatments tendencies for higher P content in leaves were observed, but the differences were not significant ($p>0.05$). The content of K was influenced both by the soil water regulation method and the age of apple–tree vegetative parts. In the younger tree parts the content of K was even several times higher than in older wood ($p<0.05$).

Removal of nitrogen with summer–pruned branches and leaves was 30.49 kg ha^{-1} in the mulch treatment and 16.64 – 17.66 kg ha^{-1} in control and fertigation treatments ($p<0.05$). Removal of potassium in the control treatment was 15.92 kg ha^{-1}, in the mulch treatment 32.81 kg ha^{-1}, but in the fertigation treatment 22.57 kg ha^{-1} ($p<0.05$). Removal of phosphorus varied from 2.20 to 4.30kg ha^{-1}, no significant differences were found among treatments ($p>0.05$).

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