POTASSIUM REMOVAL WITH GRASS IN AN APPLE ORCHARD UNDER INFLUENCE OF MULCH AND IRRIGATION

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Abstract

Potassium (K) is one of the most important nutrients necessary for many life functions of plants, like shoot growth, fruit and flower bud set, and fruit size. The aim of this study was to determine the content of potassium in orchard lawn for reduction of potassium fertilizer application and to include the potassium from mown grass into K balance and turnover calculation. The investigation was done at the Latvia State Institute of Fruit-Growing in Dobele in 2009, on the basis of an established field experiment planted in 1997 with apple (*Malus domestica* Borh.) cultivar 'Melba' (rootstock B9), trees spaced at 1.5 × 4 m distances. Three different treatments of soil moisture management were compared: control, sawdust mulch, and fertigation. Soil of the experimental plot was Pisocalcic Cutanic Luvisol (Hypereutric, Hyposkeletic); loam. Organic matter – 25 g kg^{-1}, soil reaction pH – 6.5. Plant-available P was 130.9, K – 157.7, and Mg – 102.2 mg kg^{-1}. Inter-row strips were covered with grass vegetation (*Lolium perenne* L. and *Poa pratensis* L.). Grass samples were collected during cutting, 3 times per season of 2009: May 19, June 20, and August 11. The uptake and removal of potassium was calculated as kilograms per hectare area. The concentration of potassium in the lawn and the height of grass growth were significantly influenced by the mowing time and the soil moisture treatment. These results can be a base for further studies of potassium turnover in an orchard, as well as for fertilizer planning and management.

Key words: *Malus domestica* Mill., mineral nutrition, nutrient uptake.

Introduction

Potassium (K) is one of the most important nutrients necessary for many life functions of plants, like shoot growth, fruit and flower bud set, and fruit size. Potassium facilitates the water supply in cells, and accumulation of carbohydrates. 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). Lack or surplus of potassium in the soil greatly depends on the type of farming and technologies used. It has been found that at farms where post-harvest residues remains are left on the field and ploughed down, the total loss of potassium is significantly lower, because potassium returns to the circulation (Līpenīte and Kārkliņš, 2006).

Development of integrated fruit growing in Latvia makes some restrictions for use of mineral fertilizers. These restrictions are fixed in regulations of the Latvia Council of Ministers, which have been worked out on the basis of EU guidelines as well as on the fruit and berry integrated production guidelines which provide the measures for recording of used fertilizers and mechanisms of control. The main idea is to minimaze the use of chemical substances in fruit growing and conform its use with soil conditions. Therefore regulations require the farmers to compose annual fertilizing plans based on actual (or planned) nutrient removal, therefore relevant data sets should be developed taking into consideration the modern technologies of orchard crop growing.

The rapidly increasing price of mineral fertilizers stimulates the producer, without loss of yield and income, to choose more rational growing technologies with a suitable fertilization system. It could be stated as minimal inputs for planned yield goal but taking into consideration the maintenance of soil fertility status. If the mown grass is left in the orchard, not only the nutrients come back to the turnover, but also the content of humus in the soil will increase. Thus the buffer capacity of soil increases which in turn preserves nutrients from leaching, as well as improves soil aeration so influencing positively not only the growth of apple-tree roots, but also microbiological processes in soil, increasing and preserving sustainable soil fertility (Hoagland et al., 2008). This has become especially important during the latest years, with serious concern for environment and development of organic and integrated fruit growing where mineral fertilizers are used as little as possible.

To provide the practical information for fertilizer planning it is necessary to clarify the quantity of potassium found in the mown grass depending on technologies used for water supply – mulching of soil around trees or establishment of irrigation systems, which may significantly influence the grass biomass as well as concentration of potassium in grass. The aim of this study was to determine the content of potassium in orchard lawn for reduction of potassium fertilizer application and to include the potassium from mown grass into K balance and turnover calculation.

Materials and Methods

The investigation was carried at the Latvia State Institute of Fruit–Growing, Dobele, in 2009. A field trial in three replications was set up on the basis of an orchard established in 1997, for cultivar 'Melba' on rootstock B9 (planting pattern 1.5 × 4 m). Three kinds of soil water treatment in tree strips were compared: (1) control – no water regulation, (2) sawdust mulch, and (3) fertigation, e.g. drip irrigation with fertilizer additives. In the mulching treatment, soil surface was covered with a 10–20–cm layer of sawdust which was 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, which makes 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 was 1 m wide, and during the growth season it was maintained free from grasses. The inter-row strips were 3 m wide. The grass during the experiment was mown regularly (3 – 5 times per season). The apple-trees were trimmed as a slender spindle. The average yield was 20 t ha^{-1} annually.

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

Grass samples were collected during cutting, 3 times per season of 2009: May 19, June 20, and August 11. From the start of the growing season till May 19 the average air temperature was 13.6 °C, precipitation – 9.3 mm; till June 21 – 14.8 °C and 93 mm; and till August 11 – 18 °C and 96 mm correspondingly. Grass samples were collected at distances of 0 – 15 cm, 15 – 30 cm, and 30 – 45 cm from the grass-free tree strip. During each sampling the height of grass growth was measured. Potassium content in grass was determined using flame photometrics method. Removal of K was calculated as kilograms per hectare area (kg ha^{-1}) (Kārkliņš, 1998).

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

Results and Discussion

Soil moisture management positively influenced the growth of grass in inter-row strips. The applied moisture treatments and mowing time significantly influenced the height of orchard grass growth ($p<0.05$) (Figure.1).

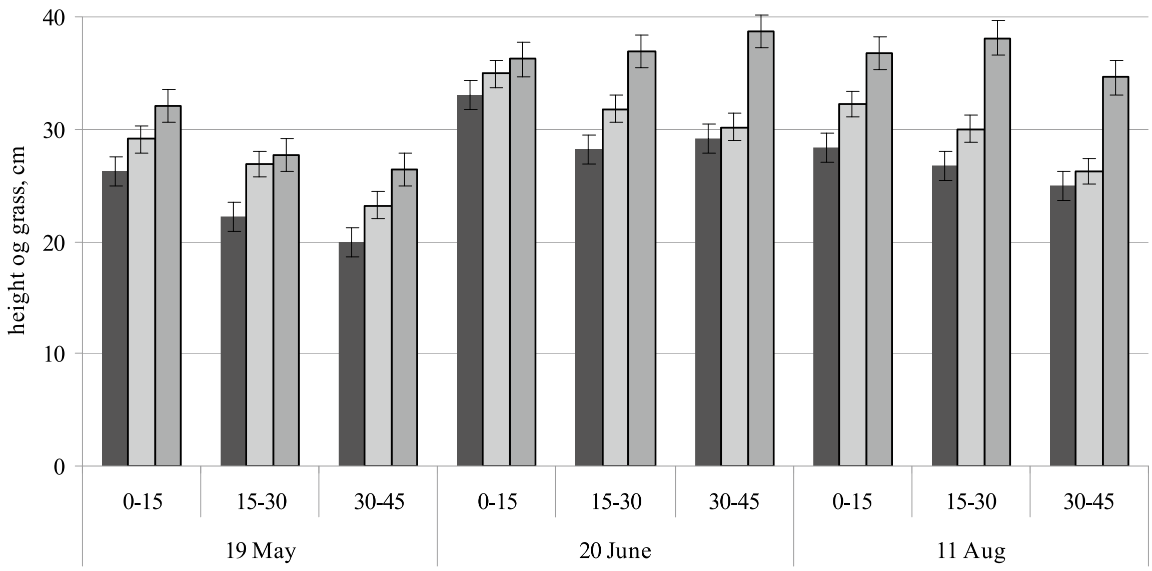

Figure 1. Height of orchard lawn at different distances from the tree strip depending on moisture treatment and mowing time, cm.
– control – mulch – fertigation

During the first mowing of grass, the growth at a 0 – 15 cm distance from the tree strip was the highest in the fertigation treatment and the shortest – in the control treatment, and this difference was statistically significant. A similar situation was observed also at a 30 – 45 cm distance from the tree strip. Whereas at 15 – 30 cm from the tree strip the shortest growth also was in the control treatment, but the growth in mulch and fertigation treatments did not differ significantly. Yet significant influence of fertigation on grass growth in these treatments was found during the second and third cutting time. This means that the influence of fertigation may appear later, besides, it must be taken into account that from the beginning of vegetation till the first mowing the precipitation was very low, which can explain the significantly lower grass growth in the control treatment. It is possible that in the control treatment the uptake of nutrients was limited as a result of the drought, as also shown by other investigations (Shengzuo et al., 2008).

During the second cut, no significant differences between treatments were found at 0 – 15 cm from the tree strip. This may be explained by the fact that fertilizer was applied in the tree strips at the beginning of the growing season. By increase of precipitation, the fertilizer uptake by grass near to the tree strip was facilitated in comparison with the first mowing time. At 15 – 45 cm from the tree strip, significantly higher grass growth was found in the fertigation treatment, while in control and mulch treatments the results showed no significant difference.

During the third cut significant differences were found between treatments at 0 – 15 cm from the grass-free tree strip. This can be explained by the positive effect of mulch and fertigation on soil moisture, as well as by the relatively high air temperature during this period. Besides, in all treatments a certain tendency was observed – along with increase of distance from the tree strip, the grass growth decreased. These differences may be the result either of the applied soil moisture treatment or the specifics of fertilization in an orchard. Fertilizer was not applied in the whole area, but only in the tree strips, which means that closer to the tree strips the inter-row grass growth could receive more nutrients along with increased uptake due to higher moisture and temperature.

The results of the investigation showed that the content of potassium in the orchard lawn grown in was influenced by the applied soil moisture regulation treatments – sawdust mulch and fertigation ($n=54$, $p<0.05$) (Figure 2).

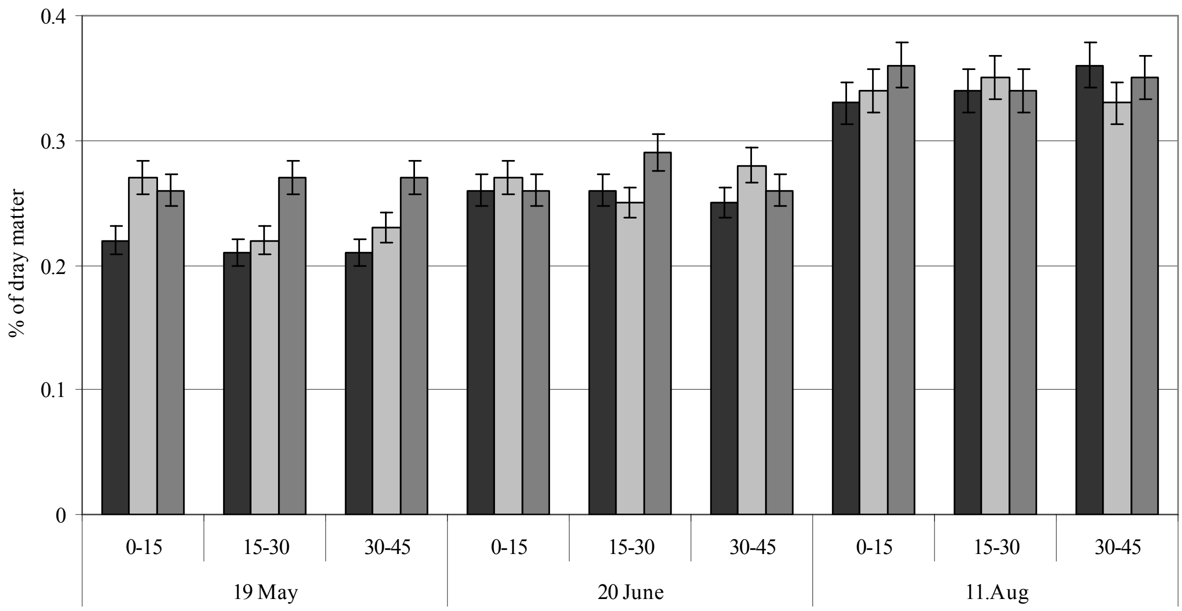

Figure 2. Content of K in orchard lawn dry matter at different distances from the tree strip depending on moisture treatment and cutting time, g kg^{-1}.
– control – mulch – fertigation

The concentration of potassium in grass was the lowest during the first cut. At 0 – 15 cm from the tree strip the lowest potassium content was found in the control treatment. In the mulch and fertigation treatments, the content of potassium was 16% higher. In control and fertigation treatments, the potassium content at 15 – 45 cm from the tree strip was similar to that at 0 – 15 cm from the tree strip, while in the mulch treatment it was 28% lower, and the difference was significant ($p<0.05$).

During the second cut, the concentration of potassium in grass was higher by 5 – 15%, yet no significant differences were found between the first and third mowing times ($p>0.05$), except in the mulch treatment where increase in potassium content was significant. The relative increase in potassium concentration may be explained by changes in precipitation and temperature during this period. The average air temperature increased for 1.2 °C. Changes in potassium concentration did not correlate with changes in precipitation, the latest increased even tenfold during this period. On June 14, very high amount of rainfall was observed – 59.5 mm, which should increase the concentration of potassium in plants, as moisture has positive influence on it (Malaguti et al., 2006). Probable that the 4 days which passed between the strong rain and the mowing of grass were not enough to influence the potassium concentration, although it has been found that potassium moves in plants rather quickly (Adamec, 2002).

During the third cut, the content of potassium in grass was by 55% higher than during the first cut and 30% higher than during the second cut. The differences were significant ($p<0.05$). During the third cut, the potassium content in grass had a tendency to increase along with the distance from the tree strip. The increase inpotassium concentration was especially expressed in the control treatment, although no statistically significant differences were found. It can be concluded with 95% probability that for the formation of 1 ton of grass dry mass, from 22 to 40 kg of potassium are required. Results of this study comply with the conclusions of other researchers (Līpenīte and Kārkliņš, 2001) that grasses need on average 27.4 kg of potassium for the production of 1 t of dry mass.

Still it is not possible to ascertain that the concentration of potassium in the lawn grass was influenced only by the mowing time. Theoretically the concentration of potassium in plants should decrease during the growing season (Nurzinski et al., 1990), but in this study it was an opposite – the concentration increased. These contradictions may be explained by the fact that the grass was cut down several times during the season, which did not allow grass to go through all developmental stages; besides it was not in the same stage of development during all mowing times. The grass mown on May 20 had already reached beginning of flowering, but on August 11 the mown grass was at a much earlier stage. However, the development stages of grass were not different among moisture regulation treatments.

The concentration of potassium could be influenced not only by air temperature and precipitation during the growth of grass, but also by other factors. Yet at all mowing times there was observed a tendency of mulch reducing the potassium concentration in the lawn.

Although the potassium concentration during the first cut was lower in the control and mulch treatments (Figure 2), the removal of potassium was the lowest in the control treatment ($p<0.05$); besides it was notably different from the mulch treatment where the potassium removal was 2 times higher, and from the fertigation treatment where the removal was 3 times higher. During the second cutting of grass, significant differences were found between the control and fertigation treatments. Fertigation increased the removal of potassium 2 times ($p<0.05$) as compared to the control (Table 1). During the third mowing significant differences were established among all three treatments ($p<0.05$): lower removal of potassium was found in the control treatment, in the mulch treatment it was 56% higher, while in the fertigation treatment – 2 times higher.

Table 1

Grass biomass and potassium uptake, kg ha^{-1}

Cut	Treatment					
	control		mulch		fertigation	
	biomass	K uptake	biomass	K uptake	biomass	K uptake
1	282.40^{a}	5.90^{a}	365.50^{b*}	8.37^{ab*}	359.33^{b*}	9.04^{a*}
2	443.54^{b}	11.17^{b}	503.39^{c*}	13.13^{bc}	542.12^{c*}	14.19^{b}
3	494.27^{c}	16.54^{c}	503.48^{c}	16.49^{b}	567.69^{c}	19.29^{c*}
Per season, kg ha^{-1}	1220.21	33.61	1372.38	37.99	1469.14	42.52

a, b, c, – significantly different within columns ($p<0.05$)
* – significantly different within rows ($p<0.05$).

Such differences were observed because the biomass of the mown grass significantly varied between moisture regulation treatments and mowing times. Till May 20 when the grass was cut for the first time, the precipitation since the start of growth season was only 9.3 mm, therefore in the fertigation and mulch treatments where the soil moisture conditions were presumably better the grass biomass was higher. These results comply with the results of other researchers showing that plant biomass significantly increases when fertigation is used (Hornig and Bünemann, 1993).

No similar studies have been done in Latvia, so there are no data about the rate of the decomposition of cut grass and return of potassium into the natural turnover, but researchers in other countries (Shengzuo et al., 2008; Tagliavini et al., 2008) have found that potassium returns into circulation already 1 – 2 years after grass mowing. Besides it has been investigated (Cazzato et al., 2004; Eason et al., 1991) that throwing of cut grass onto the tree strips significantly increases the amount of organic matter in soil, which is favourable for the potassium turnover and availability to plants.

It should be added that the results of the study could be influenced by weather conditions and other uncontrollable factors, therefore here are only some tendencies discussed. Yet a similar investigation in Latvian conditions was performed for the first time, and the results may become a base for further studies of potassium turnover in an orchard as well as for fertilization planning.

Conclusions

Mulching of tree strips in an apple orchard significantly reduced the concentration of potassium in the orchard lawn and the height of the cut grass growth.

The potassium concentration in orchard lawn was significantly influenced by the time of cut during the growing season and the height of grass which in turn was determined by air temperature and precipitation, stage of grass development, and other factors.

Annual removal of potassium with the biomass of orchard lawn in the control treatment was 33.61 kg ha^{-1}, in the mulch treatment it was 14% higher, and in the fertigation treatment 26% higher ($p<0.05$).

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