NITROGEN REMOVAL WITH APPLE–TREE FRUITS

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Abstract. 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 Haplic Luvisol (Hypereutric), sandy loam, interspaced with Cutanic Luvisol, sandy 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}. The aim of the investigation was to determine nitrogen removal with fruit yield taking into consideration the used soil moisture regulation method – sawdust mulch or fertigation. The applied soil moisture regulation methods (mulch and fertigation) had significant influence on the content of dry matter in apple fruits ($p<0.05$). The highest content of dry matter was found in the control treatment. A significantly higher nitrogen concentration (47 g kg^{-1}) in apple dry matter was in the control treatment, whereas in mulch and fertigation treatments nitrogen concentrations were lower (36 and 42 g kg^{-1}). The highest nitrogen concentration in dry matter was found in fruits with the biggest mass ($r=0.61$). A negative significant ($p<0.05$) correlation was found between nitrogen concentration and trunk diameter ($r=-0.85$), and between nitrogen concentration and yield ($r=-0.84$). Removal of N was 24.4 kg ha^{-1} in the control, 22.3 kg ha^{-1} in the mulch, and 25.0 kg ha^{-1} in the fertigation treatment.
Key words: fertigation, mulch, nutrient remove

Introduction

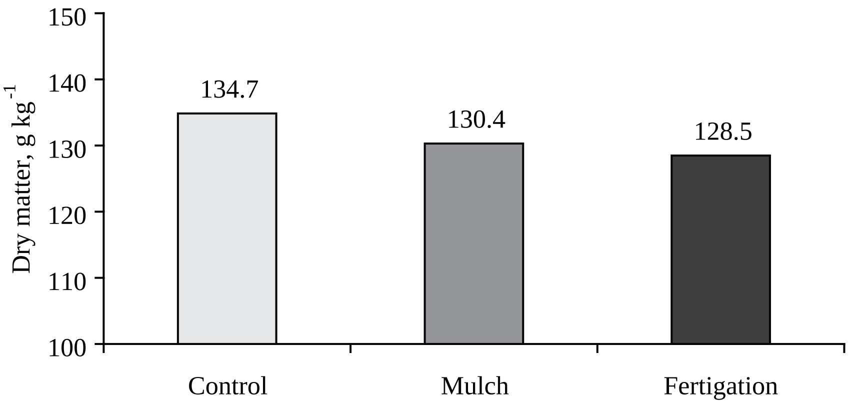
Harvesting of yield irreversibly removes plant nutrients from the orchard. Nitrogen, a biologically active and important nutrient, also is leaving the orchard, therefore and should be replaced by fertilizers for the next growing seasons. Nitrogen is consumed in relatively large quantities and is necessary for many life functions of the trees, such as growth of shoots, setting of buds and fruits, and fruit development. Nitrogen deficiency for apple–trees results in several negative consequences: decreases growth of shoots leaves become light green or yellowish, which in turn negatively influences the intensity of photosynthesis (Fallahi et al., 2001; Cmelik et al., 2006).

The main task of fertilization is to provide that part of plant nutrients which the plants need in order to obtain a good quality yield, but which cannot be supplied by soil. Yet, if the amount of nutrients turned in eith fertilizers exceeds the loss of nutrients, this is harmful both to plants and the environment. Independent of the form of N in fertilizers, when in soil it soon transforms into nitrate N-NO_3^- form and is washed out, polluting ground water and water bodies (Dong et al., 2005). 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 No. 531 and No. 406, which are worked out on the basis of EU guidelines Nr. 91/676 EEK (Nitrate directive) 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 rapidly increasing price for mineral fertilizers also stimulates the producers, without any loss of yield and income, to choose more rational growing technologies, choice of a sustainable fertilizing system. Regulations require the farmers to compose annual fertilizing plans based on nutrient removal, therefore relevant data sets should be developed taking into consideration the modern technologies of orchard crop growing. Some part of fertilizer use recommendations have been worked out in 1960s -1970s – they are more applicable for apple-trees on vigorous rootstocks. Since 1990-s apple-trees have been grown on dwarfing or dwarf rootstocks, which have a morphologically different root system, as well as different growing technologies have been used in plantations. Despite the fact that average amount of precipitation is quite satisfactory and sometimes even too wet, there are periodical water deficit in soil. Therefore some fruit growers are interested to implement any methods of soil moisture regulation, such as mulching of tree strips as well as establishment of different irrigation systems which may affect not only nutrient turnover but also their removal. The applied method of soil moisture control and plant nutrient management works parallel, and therefore key figures of fertilizer planning like nutrient requirement and removal is important and should be validated periodically. Therefore the aim of this investigation was to determine nitrogen removal with (*Malus domestica* Borh.) fruit yield taking into consideration the used soil moisture regulation method – sawdust mulch or drip irrigation with fertilizers (fertigation).

Materials and Methods

The investigation was carried out at the Latvia State Institute of Fruit – Growing, Dobele, in 2009. It was done on the basis of a field trial planted with one year maiden trees in 1997 (Rubauskis et al., 2004). The planting distance of trees was 1.5 × 4 m. The agrochemical investigations were done for trees of cultivar 'Melba' on the dwarf rootstock B 9. The canopy of trees was trained as slender spindle. The obtained average yield per year was 20 t ha^{-1}.

The meteorological data were collected by a`Lufft`



* significantly different ($p<0.05$)
Figure 1. The content of dry matter in apple fruits (g kg^{-1}).

meteorological-station placed at the institute. The climate situation was as following in 2009: the period of vegetation, when air temperature is 5 ºC or higher was 204 days (average of long-term observations 135–145 days); the average air temperature was 8.1 ºC (long-term average 5.5 ºC) and annual precipitation was 531 mm (long-term average 560 mm), however, it should be pointed out that precipitations in vegetation the period was only 312 mm. Soil of the experimental plot was Haplic Luvisol (Hypereutric) interspaced with Cutanic Luvisol, sandy loam. Organic matter content in soil was 25 g kg^{-1} (according to 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 to Egner–Riehm or DL method).

The following treatments of soil moisture regulation in tree strips (1 m wide) were compared: (1) control – no regulation methods; (2) sawdust mulch; and (3) fertigation, e.g., drip irrigation in combination with fertilizers. In the mulch treatment, soil surface was covered with a 10–20 cm layer of sawdust, which was renewed every three years for three times. 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 1m wide zone in sandy loam soil or about 25% from the orchard area. In 2009, for trees with irrigation, additional 353 liters of water were provided, in 12 applications. In the alleyways (3 m wide) grasses *Lolium perenne* L., and *Poa pratensis* L. in proportion 1:3, were sown. Some weeds such as white clover *(Trifolium repens*) and dandelion *(Taraxacum officinale)* were also spread out into the grass lawn. In 2009, the trees were provided with 9 g of N and 10 g of K using ammonium and potassium nitrates. In the control and mulch treatments they were provided once during the flowering of apple-trees, but in the fertigation treatment – bi–weekly (3 times) expanded into 6 weeks after flowering of apple-trees. The grass in alleyways was not fertilized.

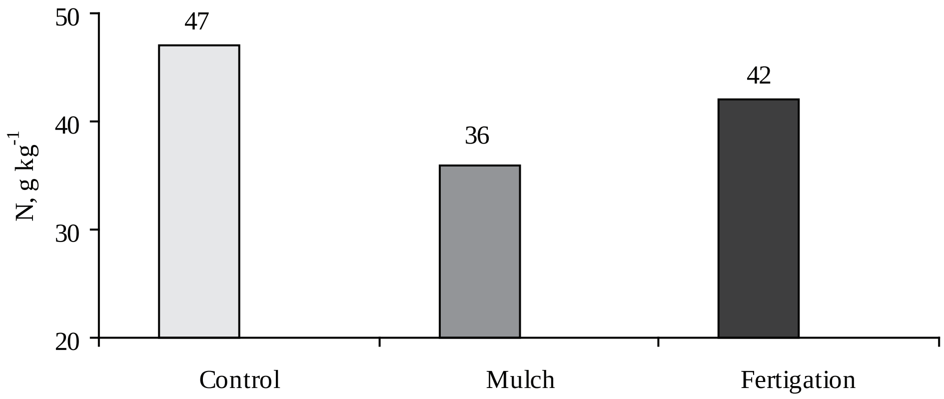
The fruits were harvested on August 24. Fruit samples were taken as 1 kg of randomly chosen fruits from each treatment. In the fruit samples of dry matter amount (ISO 6496) and total nitrogen (Kjeldahl method, wet digestion) were determined. The removal of nutrients was calculated as kilograms per hectare area (kg ha^{-1}) (Kārkliņš, 1988). The results of the investigation were analyzed using analysis of variance *ANOVA*, as well as descriptive statistics *(Descriptic statisti)* and correlation.

Results and Discussion

The applied methods of soil moisture regulation – mulch or fertigation – had significant ($p<0.05$) influence on the content of dry matter in apple fruits (Figure 1).

The lowest content of dry matter was in the fertigation treatment – 128.5 g kg^{-1}, but the highest – 134.7 g kg^{-1} in the control treatment. These differences may be explained by the different moisture supply in the 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. This might indicate that apple-trees grown with mulch or fertigation had more suitable moisture situation than those growth in the control treatment, which, in its turn may indicate that apples during their growth and development had higher water intake in these treatments. The content of dry matter did not differ significantly ($p>0.05$) between the mulch and fertigation treatments. The investigation showed that the control treatment hard relatively higher data variation ($S_x = 6.2$). In mulch and fertigation treatments the data variation was 2 times lower. Variation of data possibly indicates variation of moisture situation during apple growth. Mulch and fertigation provide an optimal moisture regime so the moisture in plants is supplied regularly, while in the control treatment moisture supply is unstable, therefore apple trees as well as fruits often may lack it (Evans and Proebsting, 1985; Rubauskis, 2005).

Results of the investigation demonstrate that the nitrogen concentration in plants was significantly influenced by the used soil moisture regulation treatments – sawdust mulch and fertigation ($p<0.05$) (Figure 2).



* significantly different ($p<0.05$)
Figure 2. The content of nitrogen in apple fruit dry matter (g kg^{-1}).

The highest concentration of nitrogen in fruits was in the control treatment, in fertigation treatment it was lower by 11%, but in the mulch treatment – by 24%; the difference was significant ($p<0.05$). These data do not contradict with the results obtained by other researchers (Dris et al., 1998) who have found that in early-ripening apple cultivars (like ‘Melba’) nitrogen concentration is 40 to 70 g kg^{-1}. The significantly lower nitrogen content in the mulch treatment may be explained by the fact that nitrogen which during decomposition of sawdust is used by microorganisms for their life functions has not yet been fully released and the immobilization process continues. It has been established that if the organic matter at the beginning of decomposition has ratio of C:N up to 20, then mineralization exceeds immobilization, but if this ratio is over 30, then immobilization dominates over mineralization (Wickramasinghe et al., 1985). In sawdust, depending on its origin (deciduous trees or conifers, and of tree species), the C:N ratio may reach even 400 (Shengzuo et al., 2008), so it is possible that the decaying process of sawdust has not been finished. There are various, even contradictory observations about the length of decay of sawdust. Some researchers (Haynes and Goh, 1980) have found that sawdust decomposes during 2–3 years, but others (Shengzuo et al., 2008) have established that decomposition may last until 7–8 years depending on conditions. Nitrogen in plants is dominating as an organic compound, and it is found also in a mineral form either as NO_3^- or NH_4^+ ions (Dong et al., 2005). In this study only total N was determined in apple fruits. In moist soil, nitrogen is more easily available to plants (Thakur and Shekhar, 1982), and it is possible that, if fertigation is applied, nitrogen uptake could be higher. This is indicated by our data and also by data of other authors (Parchomchuk et al., 1994; Malaguti et al., 2006).

Several correlations were found between nitrogen concentration in dry matter and yield level (Table 1). Acomparatively close but non-significant correlation ($p>0.05$) was found between average fruit mass and nitrogen concentration in fruits. The higher was the fruit mass, the higher was the nitrogen concentration ($r = 0.61$). This complies with the results obtained by other researchers (El-Boray et al., 2006) who investigated the uptake of nitrogen by apple-trees and fruits at certain N concentrations in soil. A significant and close correlation ($p<0.05$) was found between the content of dry matter and per cent of fallen apples ($r = 0.85$). This means that the part of fallen apples was larger from trees which had higher content of dry matter in fruits. It was already mentioned that significantly highest content of dry matter was found in apples of the control treatment (Figure 1).

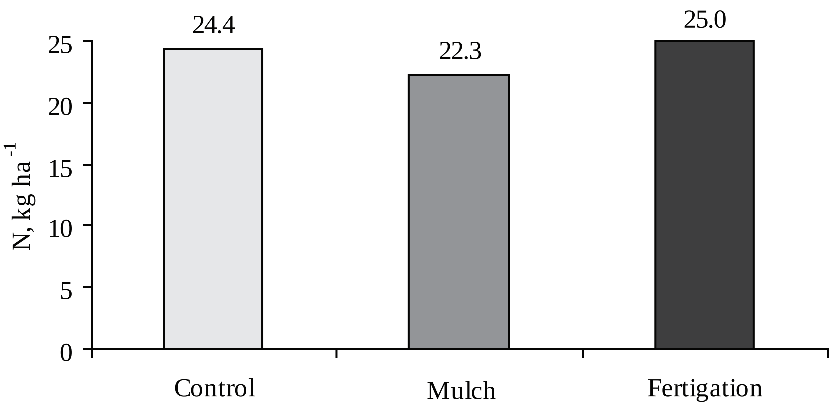
This shows that soil moisture deficit consed premature fruit drop. To give professional explanation of the results, additional research is needed. A medium close, non-significant correlation ($r = 0.58$) was found between the share of non-standard fruits and the content of dry matter.

Table 1

Results of correlation analysis

Parameter	Average fruit mass, g	Fallen fruits, %	Non-standard fruits, %	Trunk diameter, cm	Yield, t ha^{-1}	N, % in dry matter
N, % in dry matter	0.61	0.43	0.40	-0.86**	-0.74*	1
Dry matter, %	0.55	0.85*	0.58	-0.62*	-0.56	0.30

* correlation significant at $p<0.05$
** correlation significant at $p<0.01$



* significantly different ($p<0.05$)
Figure 3. Removal of nitrogen by apples, kg ha^{-1}.

Next, the bigger was the tree trunk diameter, the lower was the nitrogen concentration in fruits ($r = -0.86$), wich may mean that the more nitrogen is used by the tree for biomass growth, the less is contained in fruits. Results of the investigation show that with the increase of fruit yield the nitrogen concentration in the fruits decreases ($r = -0.74$). This may signify that a tree has some certain limit in possible uptake of nutrients. To confirm this, additional research is necessary and correlation must be found also for a year of low yield.

Although concentration of nitrogen in fruits was significantly higher in the control treatment (Figure 2), removal of this element (kg per ha) with the fruit yield was similar ($p>0.05$) in all treatments (Figure 3). In 2009 it was 22.3 kg from the mulch treatment, 10.9% more from the control treatment, and 11.2% more from the fertigation treatment compared with mulch treatment.

In the previous study (Surikova and Kārkliņš, 2009), showed that removal of nitrogen with vegetative parts during summer pruning was 16.64 kg of nitrogen from 1 ha of apple orchard in control treatment, 30.48 kg in mulch treatment, and 17.66 kg in fertigation treatment. So together with the yield, without applying soil moisture treatments, nitrogen removal was 31.04 kg ha^{-1}, which does not significantly differ from the data obtained in Latvia during 1960s – 1970s (Dimza and Gross, 1994), when nitrogen removal for apple cultivar 'Antonovka' on seedling rootstocks was 30.3 kg ha^{-1} (including branches removed by tree pruning). Similar nitrogen removal was found also in the fertigation treatment in our experiment – 32.66 kg ha^{-1}, but, by mulching tree strips, nitrogen removal increased up to 70% and reached 52.79%.

Conclusions

1. The applied soil moisture regulation methods (mulch and fertigation) had influence on the dry matter content in apple fruits. A significantly higher ($p<0.05$) nitrogen concentration (47 g kg^{-1}) was in the fruit dry matter of the control treatment, while in the mulch and fertigation treatments nitrogen concentrations were similar (36 and 42 g kg^{-1}).
2. The highest nitrogen concentration was in fruits with the biggest mass ($r=0.61$). A significantly negative correlation ($p<0.05$) was found between nitrogen concentration and tree trunk diameter ($r = -0.85$) and between nitrogen concentration and yield ($r = -0.84$).
3. Removal of N with apple fruits was 24.4 kg ha^{-1} in the control treatment, 22.3 kg ha^{-1} in the mulch, and 25 kg ha^{-1} in the fertigation treatment ($p>0.05$).

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