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Effects of foliar applied fertilizers and removal of runners on the yield and berry quality of strawberry cultivar 'Polka' on black plastic mulch

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Experiment was carried out with strawberry cultivar 'Polka' at Polli Horticultural Research Center in 2003–2006 in collaboration with Kemira GrowHow. The objective of the experiment was to study the influence of foliar fertilization and removal of runners on yield and fruit quality of cultivar 'Polka' on black plastic mulch under conditions of adequate fertilization of soil. Plants were grown in double rows covered with 1.2 m wide black plastic. There were 8 variants: 1) non-fertilized without runners (control); 2) non-fertilized with runners; 3) sprayed with Phosfik; 4) sprayed with Ferticare 14-11-25; 5) sprayed with Kemira strawberry foliar fertilizer; 6) sprayed with Aton AZ; 7) sprayed with Boramin Ca; 8) sprayed with Maxflow Mg. In all variants with foliar fertilizers, the runners were removed during picking of fruits.

The results showed that compared to the control (non-fertilized and without runners) the plants in non-fertilized variant with runners not removed showed yield decrease of 10 % in first crop year. In three-years average yield, the amount of second grade fruits was higher, and the share of small fruits was enhanced in this variant. All foliar fertilizers increased the percentage of first grade fruits in the total yield of the first year for 2.5–4.8 %. Plants treated with Aton AZ gave a significantly higher yield. Aton AZ gave an increase in average berry weight over all three years.

Key words: *Fragaria × ananassa*, foliar fertilization, yield quality, removing of runners.

Introduction. According to Statistics of Estonia, the total strawberry cultivation area in 2006 was 814 ha and the average yield 2.1t ha^{-1}. The most widely grown cultivar in Estonia is 'Polka' because of its reasonably good winter-hardiness and good yield. 64 % of plantations are established on black plastic mulch as this method suits best under Estonian climate (Lille et al., 2003; Karp et al., 2002; Kikas, Luik, 2002; Kikas, 1997). On black plastic mulch the yield ripens earlier and the berries remain clean. The mulch also helps to maintain moisture of the soil, prevents weed-growth and protects the soil from nutrient loss (Boyce and Reed, 1983; Kasperbauer, 2000; Kivijärvi, 2002). However, there are also drawbacks in using plastic mulch.

Soil compaction and insufficient aeration are the major problems. As the plantation gets older, the uptake of nutrients is restricted and applying of additional fertilizers may be complicated. The mulch can also be a favourable procreation place for strawberry mites (Metspalu et al., 2001). This can lead to decreased yields and losses in berry quality. One possibility of compensating nutrient deficiency is the use of foliar fertilizers. Foliar application of fertilizers is considered more ecologically sound than soil fertilization (Lanauskas et al., 2006). Therefore, the number of foliar fertilizers available on the market has recently increased. The effect of fertilizers depends on the nutrient content of soil, soil texture, organic matter and pH (Lacertosa et al., 1999). On soils with high nutrient levels the effect of foliar fertilizers is minute (Latet et al., 2002; Neuweiler, 1997; Albregts and Howard, 1987). Cultivars react diversely to fertilization (Michalski, 1997; Klaas, 2001). The objective of our research was to evaluate the effect of different foliar fertilizers and removing of runners on the yield and berry quality of strawberry cultivar 'Polka' on black plastic mulch under conditions of adequate fertilization of soil.

Object, methods and conditions. The investigations were carried out at Polli Horticultural Research Center from 2003 to 2006 in collaboration with sales company Kemira Grow How, which suggested the list of fertilizers for testing. Soil in the experimental area was sandy loam. Soil pHkcl was 6.2 and organic C content was 4.6 %, which is suitable for strawberry production (Matala, 1994). The content of P and K was high (207 and 242 mg kg^{-1}, respectively); Ca Mg and Cu levels were sufficient in the soil (1 850, 121, 5.2 mg kg^{-1}). B and Mn content were low (0.69 and 81 mg kg^{-1}). The test plot with cultivar 'Polka' was established in the spring of 2003. It was planted in double rows covered with 1.2 m wide black plastic mulch with row spacing 140 cm and plant spacing 33 cm. The experiment had a complete randomized block design with four replications of 50 plants per variant. The plot had no irrigation system, water was provided by rain.

Before blooming time the plants were sprayed with Topas 100 EC and Fastac 50 EC mix; for weed control Basta 150 SL was used between rows.

The composition of fertilizers used in the experiment:

1. Phosfik, NPK 3-12-15, B 0.01 %, Cu 0.02 %, Mn 0.02 %, Mo 0.001 %, Zn 0.02 %
2. Ferticare 14-11-25, NPK 14-5-21, Mg 1.4 %, S 1.8 %, B 0.02 %, Cu 0.01 %, Mn 0.1 %, Fe 0.1 %, Mo 0.002 %, Zn 0.01 %, Co 0.001 %
3. Kemira strawberry foliar fertilizer, NPK 6.6-12-21
4. Aton AZ, free amino acids 6 %, CaO 1.2 %, B 0.1 %, Fe 1.1 %, Mn 0.8 %, Mo 0.1 %, Zn 1.2 %
5. Boramin Ca, free amino acids 6.5 %, CaO 10.4 %, B 0.27 %
6. Maxflow Mg, Mg 55 %

The following variants were used in the experiment:

1. No foliar fertilization, runners were removed (control);
2. No foliar fertilization, runners not removed;
3. Phosfik three times before flowering at the ratio 2 l ha^{-1} with 1 000 l ha^{-1} of water;

4. Ferticare 14-11-25, three times before flowering, 5 l ha^{-1} with 500 l ha^{-1} of water;
5. Kemira strawberry foliar fertilizer, three times during flowering. 5 l ha^{-1} with 500 l ha^{-1} of water;
6. Aton AZ, once during flowering 4 l ha^{-1} with 400 l ha^{-1} of water;
7. Boramin Ca, three times during the development of berries. 2.5 l ha^{-1} with 500 l ha^{-1} of water;
8. Maxflow Mg, once during the development of fruit 4 l ha^{-1} with 400 l ha^{-1} of water.

The interval between sprayings was one week. Runners were removed by hand alongside with picking of the berries in control variant and in all the variants where foliar fertilization was applied. Berries were harvested every other day. During harvest the yield was graded into three groups: grade I (diameter ≥ 2.0 cm), grade II (diameter < 2.0 cm) and cull berries. Every day during harvesting the mass of 100 berries was weighed and average berry weight was calculated. After the harvesting period, old leaves were removed by cutting and they were burned. 7 g of fertilizer (Cropcare 3-11-20 in 2004 and Cropcare 0-12-24 in 2005) was given to each plant through planting holes. The data were analysed by 'ANOVA', the A-factor being the year and B-factor being the effect of the fertilizer. Mean values to be compared are followed by the same letter if they are not significantly different at $P \leq 0.05$.

Weather conditions during the trial. Winters during the trial were favourable. The snow cover was sufficient to protect the plants from frost.

In April and May of 2003 air temperature was higher than usual (Table 1).

Table 1. Weather conditions during the trial period in 2004–2006: monthly mean air temperature (°C) and monthly precipitation (mm) as compared to the same figures of many years (1961–1990) in Estonia

1 lentelė. Oro sąlygos bandymo laikotarpiu 2004–2006 metais: vidutinė mėnesinė oro temperatūra (°C) ir kritulių kiekis (mm) per mėnesį palyginus su daugiamečiais duomenimis (1961–1990) Estijoje

Month Mėnuo	Air temperature Oro temperatūra (C°)					Precipitation Krituliai (mm)				
	2003	2004	2005	2006	average vidurkis	2003	2004	2005	2006	average vidurkis
April Balandis	4.2	6.5	5.4	6.6	3.4	64	4	33	16	34
May Gegužė	12.4	11.3	11.7	11.8	9.8	75	39	74	20	40
June Birželis	14.1	14.6	15.3	17.0	14.5	69	125	78	28	51
July Liepa	20.6	17.8	18.7	20.2	16.4	81	75	69	13	73
August Rugpjūtis	16.9	18.3	17.4	18.4	15.5	124	61	135	57	78

Rainfall exceeded the average by two times. June was chilly with the rainfall being 34 % higher than average. The average air temperature in July of 2003 was highest compared to other trial years +20.6 °C. Rainfall was a bit above average.

In April and May of 2004 the rainfall was poor but in June it exceeded the average by 2.5 times and compensated the shortage. Warm summer-like weather in the end of April and beginning of May was followed by abrupt decrease in temperature and night frost in mid-May (-4.5 °C on the 13th of May). The following months were average in terms of air temperature and rainfall.

The spring of 2005 was rather cool until the end of May. The first half of July was arid with only 17.4 mm of rainfall in two weeks. Daily air temperature maximum reached 30 °C. Rain started again during the second half of July and there was 135 mm of rainfall in August (1.7 times above average).

2006 was the most unfavourable year of the trial. There were major fluctuations in the amount of rainfall. Starting from April the rainfall was below average. July was exceptionally arid with no rain at all. The daytime air temperature exceeded 30 °C during 10 days and maximum air temperature measured in July was 37 °C.

Results. During the first harvest year there was an increase in yield (in comparison with the control) with treatments of foliar fertilizers Phosfik, Ferticare 14-11-25 and Aton AZ by 61 g, 75 g and 76 g per plant, respectively. The average yield of three harvests was 321–367 g per plant depending on the variant. Treatment with Aton AZ resulted in a significant increase of average yield by 43 g per plant (1.5 t ha^{-1}). Other foliar fertilizers did not affect the yield significantly. Non-removal of runners affected the yield only during the first harvest year, the loss in yield was 1.9 t ha^{-1} (10 % of yield).

Strawberry yield very varied from year to year. In 2004, the first harvesting year, the average yield per plant was 603 g (21.1 t ha^{-1} as calculated on area basis) (Table 2). During the next years there was constant decrease in yield. In the third year the yield dropped significantly, yield per plant was 160 g or 5.6 t ha^{-1} when calculated on hectare basis.

Average berry weight increased as a result of treatment with Aton AZ in the first harvest year and as the average over all trial years (Table 2). Other foliar fertilizers did not have a positive effect on berry weight. Keeping the runners between rows also had negative effect on berry weight. In three years average, non-removal of runners caused a decrease in average berry weight by 1.3 g as compared to the control. There was a remarkable decrease in berry weight in the second and third years of harvest. The average berry weight was 15.5 g in the first year and only 6.7 g in the third year.

Table 2. Average yield per plant (g) and berry weight (g), 2004–2006
2 lentelė. Vidutinis augalo derlius ir uogos masė 2004–2006 metais

Variant Variantas	Yield per plant Augalo derlius (g)				Berry weight Uogos masė (g)			
	2004	2005	2006	effect of fertilization tręšimo įtaka	2004	2005	2006	effect of fertilization tręšimo įtaka
Non foliar fertilized without runners (control) Netręštos per lapus, be ūsų (kontrolė)	572 b	236 a	165 c	324 a	15.3 abc	12.0 c	6.7 bc	11.3 cd
Non foliar fertilized, with runners Netręštos per lapus, su ūsais	519 a	280 a	166 c	321 a	14.4 a	9.9 a	5.8 a	10.0 a
Sprayed with Purkštos Phosfik	633 cd	236 a	122 a	330 a	14.9 ab	11.6 bc	6.4 b	11.0 bc
Sprayed with Purkštos Ferticare 14-11-25	647 cd	269 a	141 ab	352 ab	16.3 cd	11.8 c	6.6 bc	11.6 de
Strawberry foliar fertilizer Tręštos braškių trąšomis, purškiamomis per lapus	608 bcd	234 a	181 c	341 ab	15.4 abc	10.1 ab	6.9 c	10.8 b
Sprayed with Purkštos Aton AZ	648 d	281 a	172 c	367 b	16.9 d	11.8 c	7.0 c	11.9 e
Sprayed with Purkštos Boramin Ca	603 bcd	231 a	160 bc	331 a	15.5 abc	12.1 c	7.1 c	11.6 de
Sprayed with Purkštos Maxflow Mg	595 bc	258 a	175 c	342 ab	15.6 bc	11.8 c	7.0 c	11.5 de
Effect of year Įtaka per metus	603 c	253 b	160 a		15.5 c	11.4 b	6.7 a	

The share of grade I fruits in the yield decreased with the age of the plantation (Table 3). In 2004 grade I fruits formed 87.1 %, in 2005 – 75.3 % and in 2006 – 50.6 % of the total yield. Retaining the runners caused a 4.8 % decrease in the amount of grade I fruits in the third trial year and 3.8 % on average of all years.

Table 3. Share of I and II grade berries in yield (%), 2004–2006
3 lentelė. Pirmos ir antros rūšies uogų kiekis (%) 2004–2006 metais

Variant Variantas	I grade berries (%) in yield Pirmos rūšies uogų, %				II grade berries (%) in yield Antros rūšies uogų, %			
	2004	2005	2006	effect of fertilization tręšimo įtaka	2004	2005	2006	effect of fertilization tręšimo įtaka
Non foliar fertilized without runners (control) Netręštos per lapus, be ūsų (kontrolė)	84.3 a	77.3 c	51.8 bc	71.1 abcd	6.1 bc	10.6 ab	35.5 ab	17.4 a
Non foliar fertilized, with runners Netręštos per lapus, su ūsais	84.7 ab	70.4 ab	47.0 a	67.3 a	7.0 c	19.3 c	40.7 b	22.3 b
Sprayed with Purkštos Phosfik	88.8 c	78.5 c	50.6 abc	72.6 cd	4.5 a	13.1 b	35.7 ab	17.8 a
Sprayed with Purkštos Ferticare 14-11-25	89.1 c	80.0 c	52.2 c	73.7 d	4.2 a	8.9 a	34.1 a	15.7 a
Strawberry foliar fertilizer Tręštos braškių trąšomis, purškiamomis per lapus	87.2 c	66.0 a	51.7 bc	68.3 ab	4.7 a	10.2 ab	34.5 a	16.4 a
Sprayed with Purkštos Aton AZ	88.5 c	76.1 bc	47.5 ab	70.7 bc	4.1 a	12.9 b	36.7 ab	17.9 a
Sprayed with Purkštos Boramin Ca	86.8 bc	77.8 c	54.7 c	73.1 cd	5.0 ab	10.5 ab	34.2 a	16.6 a
Sprayed with Purkštos Maxflow Mg	87.8 c	75.8 bc	50.9 abc	71.5 cd	4.5 a	10.8 ab	36.8 ab	17.3 a
Effect of year Įtaka per metus	87.1 c	75.3 b	50.6 a		5.0 a	12.0 b	36.0 c	

The relative importance of grade II fruits significantly increased in the third trial year forming 36 % of the total yield (Table 3). When runners were left to grow in the field the share of grade II fruits increased by 8.7 % in the second trial year and 4.9 % as average in the trial. The positive effect of foliar fertilizers (except Boramin Ca) was expressed only in the first trial year – the share of II grade fruits decreased by 1.4–2 %.

The amount of cull berries in the yield ranged from 7.9 to 12.9 % (Table 4). All foliar fertilizers except Boramin Ca and Kemira strawberry foliar fertilizer reduced the share of cull fruits in the first trial year.

Table 4. Share of cull berries in the yield (%), 2004–2006
4 lentelė. Rinktinių uogų dalis derliuje (%) 2004–2006 metais

Variant Variantas	Cull berries per plant Rinktinių uogų ant augalo (g)			
	2004	2005	2006	effect of fertilization trešimo įtaka
Non foliar fertilized without runners (control) Netręštos per lapus, be ūsų (kontrolė)	9.7 b	12.1 a	12.7 a	11.5 a
Non foliar fertilized, with runners Netręštos per lapus, su ūsais	8.3 ab	10.4 a	12.3 a	10.3 a
Sprayed with Phosfik Purkštos Phosfik	6.7 a	8.5 a	13.7 a	9.6 a
Sprayed with Ferticare 14-11-25 Purkštos Ferticare 14-11-25	6.8 a	11.2 a	13.8 a	10.6 a
Strawberry foliar fertilizer Tręštos braškių trąšomis, purškiamomis per lapus	8.1 ab	23.9 b	11.4 a	14.5 b
Sprayed with Aton AZ Purkštos Aton AZ	7.4 a	11.3 a	15.8 a	11.5 a
Sprayed with Boramin Ca Purkštos Boramin Ca	8.2 ab	11.7 a	11.1 a	10.4 a
Sprayed with Maxflow Mg Purkštos Maxflow Mg	7.8 a	13.5 a	12.3 a	11.2 a
Effect of year Įtaka per metus	7.9 a	12.8 b	12.9 b	

Discussion. Strawberry plant produces runners abundantly especially in the first growth year. Development of runners demands nutrients and can cause a down-trend in yields. Keeping of runners can cause a yield loss of 22–46 % (Liias, 1968). In our investigation remarkable yield losses due to keeping of runners were observed only in the first year. Keeping of runners did not have any effect on yields during other trial years, but increased the amount of grade II fruits and reduced the average berry weight.

In our trial foliar fertilizers affected the yield of strawberry cultivar 'Polka' only in the first growth year. Similar research in Poland on foliar fertilization (Michalski, 2001) also confirmed an increase in yields only in the first harvest year. In the present investigation the best foliar fertilizer for strawberry cultivar 'Polka' was Aton AZ. Positive effect of Aton AZ on strawberry yields and quality has been confirmed also by investigations done at the Institute of Agricultural and Environmental Sciences, Department of Horticulture, Estonian University of Life Sciences (http://www.eau.ee/~aiandus/teaduspv.html).

Fertilization by means of spraying solution on leaves is not the predominant way of applying nutrients to plants, but can be considered as an additional opportunity for nutrient uptake. Weather conditions during flowering, development of berries and yield formation also play important role in yield and quality of berries. In 2004 obviously a lot of nutrients were removed from the soil with the high yield and foliar fertilizers

failed to compensate the loss in consecutive years. In 2005 and 2006 weather was hot and arid during the development of berries. This presumably caused the low yield and low berry weight. Drip irrigation could have been a tool enabling to increase the yield to some extent but establishing the irrigation system is expensive and not always economically feasible.

Researchers have not reached a consensus on the effectiveness of yield irrigation. Research groups of Pires (Pires et al., 2006) and Uselis (Uselis et al., 2008) have stated that in their trials strawberry irrigation did not influence essentially the productivity. Parikka (2006) has also pointed out that weather conditions during harvest season and cultivar had more influence on fruit quality than the irrigation method. On the contrary, other researchers (Krüger et al., 1999; Krüger et al., 2002) have found that irrigated plants had significantly higher yields than non-irrigated ones.

Conclusions. 1. For strawberry cultivar 'Polka' foliar fertilizer Aton AZ is suitable. There is an increase in average yields and berry weight.

2. Not removing the runners from plants has negative effect on the total yield in the first year. On the average over three years, there is a decrease in berry weight and an increase in the amount of grade II berries. In order to obtain a high quality yield, runners must be removed during harvest.

3. Foliar fertilizers cannot compensate plant stress caused by extreme weather condition.

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Tręšimo per lapus ir ūsų pašalinimo įtaka ant juodo plastikinio mulčio auginamų ‘Polkos’ veislės braškių derliui ir uogų kokybei

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Santrauka

Bandymas atliktas su braškių veisle ‘Polka’ Polli sodininkystės ir daržininkystės tyrimų centre 2003–2006 metais bendradarbiaujant su UAB „Kemira GrowHow“. Bandymo tikslas – ištirti tręšimo per lapus ir ūsų pašalinimo įtaką ant juodo plastikinio mulčio auginamų ‘Polkos’ veislės braškių derliui ir uogų kokybei, kai dirvoje yra pakankamai maisto medžiagų. Braškės augintos dviem eilėmis, uždengtos 1,2 m pločio juoda plastikine plėvele. Tirti 8 variantai: 1) netręštos braškės be ūsų (kontrolė); 2) netręštos braškės su ūsais; 3) purkštos Phosfik; 4) purkštos Ferticare 14-11-25; 5) purkštos Kemira trąšomis per lapus; 6) purkštos Aton AZ; 7) purkštos Boramin Ca; 8) purkštos Maxflow Mg. Visuose variantuose, kuriuose braškės tręštos per lapus purškiamomis trąšos, skinant uogas buvo pašalinti ūsai.

Rezultatai parodė, kad, palyginti su kontrole (netręštomis braškėmis be ūsų), netręštų augalų, kurių ūsai nebuvo pašalinti, derlius pirmaisiais derėjimo metais sumažėjo 10 %. Per trejus derėjimo metus gausėjo antrarūšių ir mažų uogų kiekis. Visos per lapus purškiamos trąšos 2,5–4,8 % padidino pirmarūšių uogų procentą bendrame pirmųjų metų derliuje. Augalai, apdoroti Aton AZ, davė kur kas didesnį derlių. Aton AZ per trejus metus padidino vidutinę uogos masę.

Reikšminiai žodžiai: *Fragaria* × *ananassa*, tręšimas per lapus, derliaus kokybė, ūsų pašalinimas.