TREATED MINERAL WATER IN PRODUCTION OF HOPS

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ABSTRACT

The aim of research was to investigate plant growth and development, yield, alpha acid and nitrate content in hop cones, alpha acid yield, and to make observations on pests and hop diseases if treated mineral water (‘*Mineral’*) is included in hop production. Treatments differed in ‘*Mineral green’* quantity used for watering, in inclusion of plant protection products (PPP), in ‘*Mineral yellow’* spraying and in mineral nitrogen (N) fertilization. At treatments where no mineral N was used, the yield was significantly lower compared to the treatments with conventional N fertilization. If ‘*Mineral’* products were included in conventional production, this resulted in a little higher yield compared to the conventional production, but the differences in yield could not be statistically confirmed. Production of hops only with ‘*Mineral’* watering and spraying, without PPP and mineral fertilizers failed in 2009 because of the outbreak of hop downy mildew – primary infection was strong at the start of the growing season. After Al-fosetyl spraying there was no such need any more and finally hop was produced with reduced PPP application on a large scale, but as a result the yield was also lower.

Key words: hops, *Humulus lupulus* L., treated mineral water, Mineral, yield

OBDELANA MINERALNA VODA V PRIDELAVI HMELJA

IZVLEČEK

Namen raziskave je bil preučiti vpliv vključitve obdelane mineralne vode (pripravka Mineral) v pridelavo hmelja na rast in razvoj rastlin, vsebnost alfa kislin in nitratov v storžkih, pridelek storžkov, pridelek alfa kislin in zdravstveno stanje. Obravnavanja se razlikujejo po vključevanju zalivanja s pripravkom '*Mineralom zeleni'*, vključevanju škropljenja s sredstvi za varstvo rastlin (FFS), škropljenju z '*Mineralom rumeni'* in dognojevanju z N. V primerjavi s konvencionalnim dognojevanjem z dušikom je bil pridelek značilno manjši pri obravnavanjih, kjer nismo dognojevali z N. Če smo v konvencionalno pridelavo vključili zalivanje in škropljenje s pripravkoma '*Mineral'*, se je nakazal večji pridelek, vendar razlike niso bile statistično značilne. Poskus ekološke pridelave hmelja cv. Celeia (brez uporabe mineralnih gnojil in FFS) z zalivanjem in škropljenjem s pripravkoma '*Mineral*' v vremenskih razmerah leta 2009 ni popolnoma uspel, saj smo morali dvakrat škropiti s pripravkom na osnovi Al-fosetil. Ostalemu škropljenju s FFS smo se sicer lahko izognili, vendar se je to odrazilo v zmanjšanju pridelka.

Ključne besede: hmelj, *Humulus lupulus* L., obdelana mineralna voda, Mineral, pridelek

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1 INTRODUCTION

Each product has to be practically tested to be approved for wider use. In the investigation Slovenian products '*Mineral green*' and '*Mineral yellow'* – treated mineral water produced by Planet of Health [10] – were tested in different combinations in hop production.

The investigation continued from the previous years [3,4]. In 2008 ecological production of Celeia hop cultivar with '*Mineral'* was estimated as promising. Even though no mineral fertilizers and plant protection products (PPP) were used, the yield of hop cones was around 1200 kg/ha dry matter (DM). Health condition of hops was satisfactory with only '*Mineral'* products used (watering with '*Mineral green'* 320 l/ha in autumn + 50 l/ha in May + 25 l/ha in June) and spraying with '*Mineral yellow*' eight times in the season). But, the results of one year are not conclusive enough to guarantee that this would happen every year because the weather conditions in 2008 were not favourable for the population of spider mite. It could be concluded at that time that the use of '*Mineral'* products has either a positive effect on the natural resistance of hop plants, or causes the natural enemies trying to hold pests back to express themselves even more. An effective combination of '*Mineral'* use in conventional production of Celeia hop cultivar was not determined in 2008. It was decided that the experiment should continue in the years to follow [3,4].

Plant growth and development, yield, alpha acid content, nitrate content in hop cones and alpha acid yield were determined and observations on pests and hop diseases were studied in 2009 to determine an appropriate combination of '*Mineral'* products to be included in conventional hop production and to try to produce hops without PPP and mineral fertilizers and only with the use of '*Mineral'* products.

2 MATERIAL AND METHODS

2.1 Material

The investigated hop cultivar was Celeia – an aromatic, late cultivar with technologic maturity from 6 September – 12 September. Expected yield is 1100 – 3200 kg/ha, alpha acid content in hop cones is between 3.0 % and 8.7 %. It is medium resistant to downy mildew, powdery mildew and gray mould, and susceptible to verticillium hop wilt [8].

'*Mineral*' products are prepared from salted mineral water which is processed with a special method. When mixed in a ratio 1:100 with fresh water it can be used as a natural fertilizer for plants with required 75 minerals for growth. A greater level of soil humidity and lower need for watering are expected. Plants should become more vital and therefore less susceptible to pests and diseases, grow and develop faster and their quality should be enhanced. '*Mineral green'* is used for watering, '*Mineral yellow'* for spraying. The difference between the products is in the way of preparation and treatment of mineral water respectively, so a different main function of product's activity is emphasized [3,4,9].

2.2 Field experiment and evaluation

The experiment was conducted in 2007 as a block trial with five fertilization variants in three replications in drip irrigated experimental field of Slovenian Institute of Hop Research and

Brewing. The size of one plot was 200 m^2, so the area under experiment was approximately 3000 m^2 in size, and in 2008 and 2009 the field experiment continued on the same location. In this paper results of 2009 are presented. Treatments were adjusted according to the previous findings [4] and were in 2009:

1 = Control –fertilization with P and K according to soil analysis, conventional N fertilization (50 + 70 + 50 kg/ha N), no foliar fertilization, spraying with plant protection products (PPP) according to the spraying program (Table 1).

2 = No fertilization with fertilizers that include P, K and N, watering with 50 l/ha '*Mineral green'* at the end of May, spraying with PPP according to the spraying program, spraying with '*Mineral yellow'* four times in the season (BBCH 25, BBCH 37-38, BBCH 61, BBCH 71-75 (Table 1)).

3 = No fertilization with fertilizers that include P, K and N, watering with 50 l/ha '*Mineral green'* at the end of May and 25 l/ha in the last decade of June, reduced spraying with PPP (only with products based on Al-fosetyl on 15 and 25 May to suppress downy mildew primary infection), spraying with '*Mineral yellow'* every 14 days, starting straight after winding up sprouts on strings (BBCH 25).

4 = No fertilization with fertilizers that include P and K, conventional fertilization with N (50 + 70 + 50 kg/ha N), watering with 50 l/ha '*Mineral green'* at the end of May, spraying with PPP according to the spraying program, spraying with Mineral yellow four times in the season (BBCH 25, BBCH 37-38, BBCH 61, BBCH 71-75).

5 = No fertilization with fertilizers that include P, K and N, watering with 50 l/ha '*Mineral green'* at the end of May, reduced spraying with PPP (only with products based on Al-fosetyl on 15 and 25 May to suppress downy mildew primary infection), spraying with '*Mineral yellow'* every 14 days, starting straight after winding up sprouts on strings (BBCH 25).

The rest of the agrotechnique was the same for all plots and performed in accordance with the good agricultural practice. '*Mineral yellow'* was used separately, not mixed with PPP.

In comparison with the treatments in 2009, the differences in 2008 season were:

- In the autumn of 2007 plots of treatments 2, 3, 4 and 5 were watered with '*Mineral green'* in the quantity of 320 l/ha.
- Treatments 3 and 4 were done without the use of PPP during the whole season.
- Each spraying with '*Mineral yellow'* was performed a day after the spraying with PPP (treatments 2 and 4).

Fifteen plots of hops were mechanically harvested one after another at the time of technologic maturity (11 September 2009). Before the harvest outer rows were removed and two inner rows were evaluated. Final plots were measured and the number of plants and strings per plot was counted. The yield was weighed plot by plot. Samples of cones were taken from each plot for analysis of alpha acid, nitrate and moisture content. Moisture content in hop cones was measured according to Analytica-EBC (1998) [1], alpha acid content according to Analytica-EBC (2000) [2], nitrate content according to DIN/EN (1998) [5].

Table 1: Dates of applied plant protection products and '*Mineral'* used in the experiment in 2009 with regard to treatment
Preglednica 1: Datumi uporabe fitofarmacevtskih sredstev in Minerala v poskusu v letu 2009 glede na obravnavanje

Application time	Performed at treatments	Product/active ingredient	Dose per ha**
12.5.09	2, 3, 4, 5	Mineral green	1:100
15.5.09	1, 2, 3, 4, 5	Aliette flash (Al-fosetyl)	2.5 kg/ha
25.5.09	1, 2, 3, 4, 5	Aliette flash (Al-fosetyl)	5 kg/ha
1.6.09	3, 5	Mineral yellow	1:100
12.6.09	1, 2, 4	Teppeki (flonicamid), Vertimec 1.8 % EC (abamectin), Cuprablau – Z ultra (copper hydroxide)	0.18 kg/ha 1.25 l/ha 3 kg/ha
15.6.09	2, 3, 4, 5	Mineral yellow	1:100 (Mineral:water)
3.7.09	1, 2, 4	Delan 700 WG (dithianon)	1.2 kg/ha
4.7.09	2, 3, 4, 5	Mineral yellow	1:100
20.7.09	1, 2, 4	Folpan 80 WDG (folpet), Nissorun 10 WP (hexythiazox), Pepelin (sulphur)	3 kg/ha 1 kg/ha 3 kg/ha
20.7.09	2, 3, 4, 5	Mineral yellow	1:100
30.7.09	1, 2, 4	Cuprablau – Z ultra (copper hydroxide), Pepelin (sulphur), Systhane 12 E (myclobutanil), Ortus 5 SC (fenpyroximate), Karate CS (lambda- cyhalothrin)	6 kg/ha 3 kg/ha 1.2 l/ha 2.4 l/ha 0.25 l/ha
30.7.09	3, 5	Mineral yellow	1:100
17.8.09	1, 2, 4	Zato 50 WG (trifloxystrobin), Vertimec 1.8 % EC (abamectin), Cuprablau – Z ultra (copper hydroxide), Pepelin (sulphur)	0.6 kg/ha 1.25 l/ha 6 kg/ha 3 kg/ha
17.8.09	3, 5	Mineral yellow	1:100

**Water consumption is 1000 l/ha. ** Poraba vode je 1000 l/ha

2.3 Soil analysis and Nmin content in soil

After the harvest in 2008 the soil was supplied with excessive amounts of phosphorus and with adequate to medium amounts of potassium (Al method) (Table 2). After the harvest in 2009 the soil was analysed for plant available nitrogen (Nmin) in the upper layer of soil (0-25 cm) with regard to treatment.

Table 2: Plant available P and K quantity and soil pH after harvest in 2008 with regard to treatment
Preglednica 2: Rastlinam dostopni P in K v tleh ter vrednost pH po obiranju v letu 2008 glede na obravnavanje

	pH in KCl	P_2O_5 (mg/100 g soil)	K_2O (mg/100 g soil)	Organic matter (%)
1	5,4	32 D	22 C	2,1
2	5,3	30 D	18 B	2,2
3	5,3	33 D	20 C	2,2
4	5,0	29 D	18 B	2,1
5	5,4	28 D	19 B	2,1

*Letters next to the numbers indicate nutrient supply class; C = adequate supply, D = excessive supply [6]
*Črke ob številkah označujejo razred oskrbljenosti z določenim hranilom; C = dobro preskrbljena, D = pretirano oskrbljena [6]

2.4 Weather conditions

In 2009 the temperatures were relatively high in May and dropped suddenly at the end of the month. Compared to the long term average, more precipitation occurred in June 2009 (174 mm) and at the beginning of July. At the beginning of August the temperatures were relatively high (Figure 1).

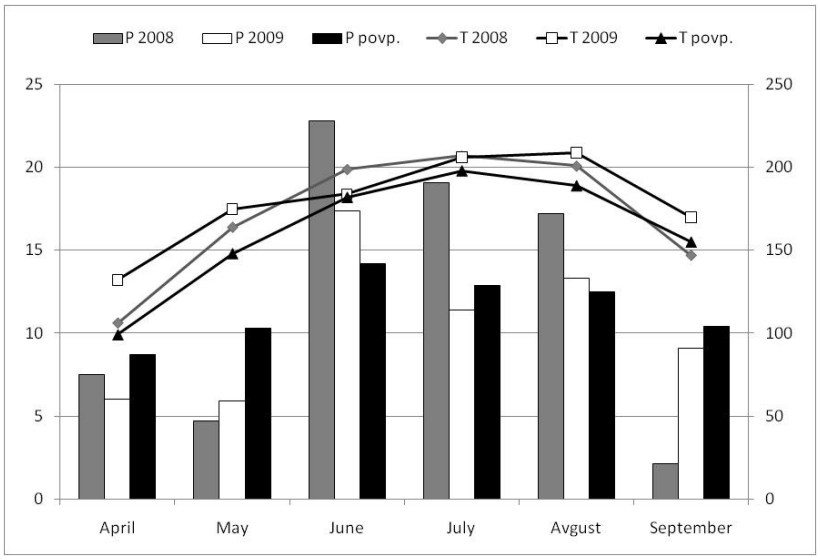

Figure 1: Weather conditions in the hop growth season in 2008 and 2009 compared to the long term average; P = precipitation amount (mm), T = decade average temperature (^{o}C)
Slika 1: Vremenske razmere v rastni sezoni hmelja v letih 2008 in 2009 v primerjavi z dolgoletnim povprečjem; P = količina padavin (mm), T = povprečna temperatura dekade

2.5 Plant growth, growth stages and assessment of pests and diseases

Plant growth was measured once to twice weekly with regard to fertilization variant. At the same time the growth stages were recorded. On each plot leaves were randomly selected at three different heights of hop plants in the same amount: leaves from the bottom of plant (0-2 m), leaves from the middle part (2-4 m) and from the upper part (4-6 m) on 11 June 2009, 3 July 2009 and 20 August 2009. Leaves were examined under a stereoscope. Spider mites (*Tetranychus urticae*) - separately mobile ones and eggs - and hop damson aphids (*Phorodon humuli*) were counted.

After the harvest 400 cones were randomly selected for each sample (plot) and infection was determined in the laboratory. Estimation of infection with downy mildew (*Pseudoperonospora humuli*), powdery mildew (*Sphaerotheca humuli* (*macularis*)), gray mould (*Botrytis cinerea*) and spider mite (*Tetranychus urticae*) was made for each cone. Downy mildew and powdery mildew were assessed on a scale of 0-4 (0 = no presence of disease, 1 = infection up to 1 %, 2 = infection from 1-5 %, 3= infection from 5-20 % and 4 = more than 20 % of infected cones). The infection percentage index was calculated using the formula of Townsend-Heuberger [7] .

3 RESULTS AND DISCUSSION

3.1 Plant growth and growth stages

There were no significant differences in plant growth among treatments in 2009 (Figure 2). There were no differences among treatments at the beginning of growth stages. At the beginning of June there were longer side sprouts at treatment 4 compared to other treatments.

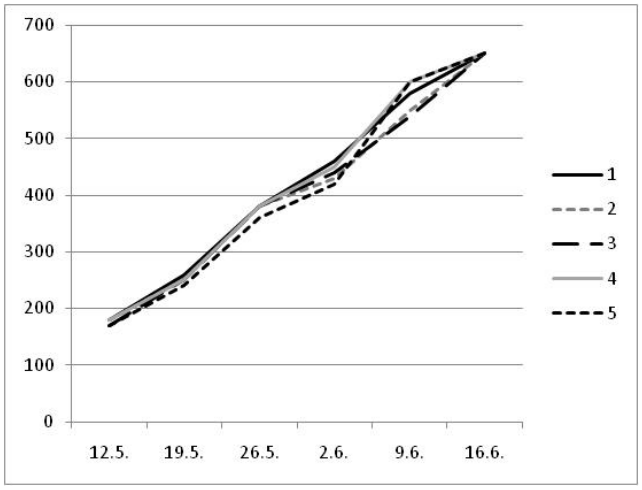

Figure 2: Plant growth with regard to treatment (1, 2, 3, 4, 5) in 2009
Slika 2: Rast rastlin glede na obravnavanje (1, 2, 3, 4, 5) v letu 2009

3.2 Nmin content in soil after harvest

There was low content of plant available N in the upper layer of the soil after the harvest (Table 3), which was probably due to the fact that the experiment was carried out on shallow soil and high precipitation quantity in June, at the time of fast growth and development of hop plants.

Table 3: Nmin content in soil (0-25 cm) after harvest in 2009 with regard to treatment
Preglednica 3: Rezultati Nmin analize zgornjega sloja tal (0-25 cm) glede na obravnavanje v letu 2009

Treatment	NO_3 – N (kg/ha)	NH_4 – N (kg/ha)	Total plant available N (kg/ha)
1	4	5	9
2	0	4	4
3	0	3	3
4	0	4	4
5	0	3	3

3.3 Plant health

3.3.1 Pests on hop leaves

At the beginning of the season, on 11 June, aphid population was similar on the parcels with treatment 1 (conventional production) and treatment 5 (reduced PPP use) (Table 4, Figure 3).

Later, after spraying with systemic insecticide (active ingredients imidacloprid and abamectin) in treatment 1, aphid population on these parcels was reduced (3 July).

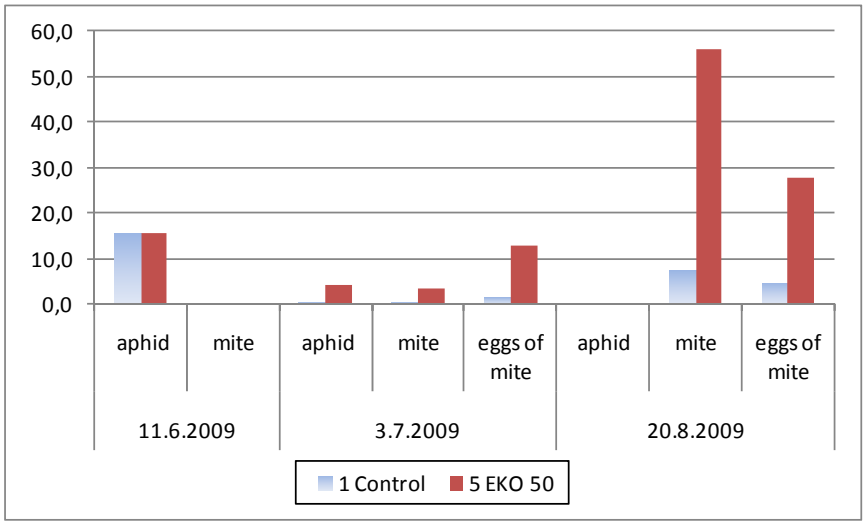

Figure 3: Average number of hop damson aphids, mobile spider mites and their eggs per leaf on different dates of assessment at treatments 1 and 5
Slika 3: Povprečno število hmeljeve listne uši, navadne pršice in jajčec navadne pršice na listih hmelja v različnih ocenjevalnih obdobjih pri obravnavanjih 1 in 5

On plots with reduced PPP use (treatment 5) spider mite (mobile stages and eggs) was present in large number (Table 4, Figure 3) and caused damage to leaves and cones. Spider mite pressure was also high on the parcels with treatment 1 (average 7.3 mites per leaf) where acaricides were used (Table 4, Figure 3). But, the difference in spider mite population among treatments where acaricides were used and not used according to the spraying program was high.

Table 4: The average number of hop damson aphids and mobile spider mites with their eggs per leaf on different dates of assessment
Preglednica 4: Povprečno število hmeljeve listne uši, gibljivih stadijev in jajčec navadne pršice na listu hmelja ocenjeno v različnih terminih

Treat. No.	11.6.2009		3.7.2009			20.8.2009		
	Aphid	Spider mite	Aphid	Spider mite	Eggs of mite	Aphid	Spider mite	Eggs of mite
1	15,64 a	0,00	0,02 a	0,42 a	1,54 a	0,00	7,30 a	4,50 a
5	15,75 a	0,00	4,04 b	3,54 b	12,72 b	0,00	56,00 b	27,70 b

[a,b] Identical letters indicate no significant difference between group means with regard to Duncan multiple test (p=0.05)
[a,b] Skupine z enako črko v indeksu znotraj stolpcev pri posameznih obravnavanjih se med seboj statistično značilno ne razlikujejo (p=0,05)

3.3.2 Disease presence on cones at harvest

At harvest, infection with downy mildew was detected at all treatments, slightly higher at treatments 2 and 5. Powdery mildew was the least present on plots with treatment 1 and the most with treatment 5 (Table 5, Figure 4).

Table 5: The share of cones attacked by diseases (in %) at harvest, 11 September 2009
Preglednica 5: Odstotek napadenosti storžkov z boleznimi v času tehnološke zrelosti hmelja (11.9.2009)

Treatment	Downy mildew*	Powdery mildew*
1	0.50[a]	0.06[a]
2	2.16[b]	0.56[b]
3	0.56[a]	0.50[b]
4	0.13[a]	0.75[b]
5	1.13[a]	0.94[b]

*Identical letter indicates that there is no significant difference between group means with regard to Duncan multiple test (p=0.05)
*Skupine z enako črko v indeksu znotraj stolpcev pri posameznih obravnavanjih se med seboj statistično značilno ne razlikujejo (Duncanov test mnogoterih primerjav, p=0.05)

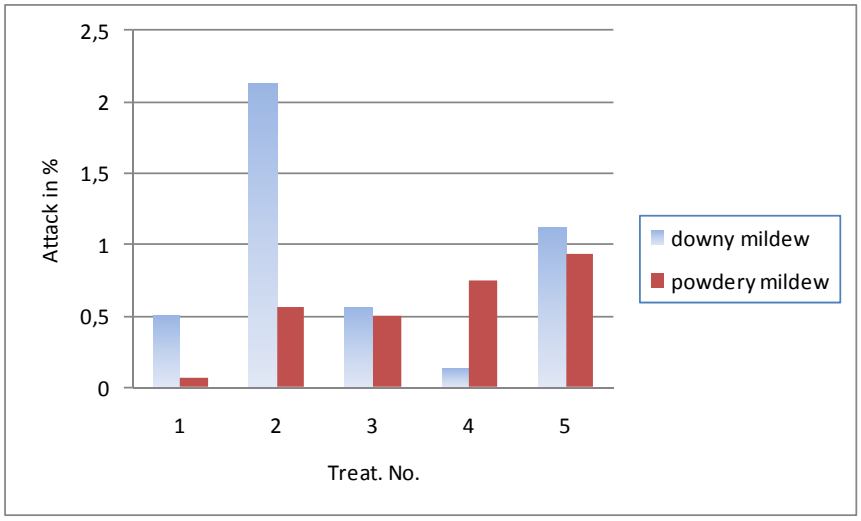

Figure 4: Cones attacked by disease at harvest, 11 September 2009
Slika 4: Odstotek napada storžkov hmelja z boleznimi v času tehnološke zrelosti, 11. september 2009

3.4 Yield, alpha acid and nitrate content in hop cones and alpha acid yield

At treatments where no mineral N was used (treatments 2, 3 and 5), cone yield and alpha acid yield were significantly lower compared to treatments 1 and 4. At treatment 4 where Mineral was included in conventional production higher yield was recorded compared to control (conventional production), but the differences in yield could not be statistically confirmed (Table 6, Figure 5).

If treatments 2 and 5 are compared (in both cases no N fertilization was included, 50 l/ha Mineral at the end of May was applied, the difference was in the use of PPP and '*Mineral'* spraying) it was observed that if PPP were not used (except Al-fosetyl at the beginning of the season) the yield decreased by 171 kg/ha although the difference could not be statistically confirmed.

Table 6: Cone yield, alpha acid content and alpha acid yield in the experiment in 2009
Preglednica 6: Pridelek storžkov (kg suhe snovi), vsebnost alfa kislin v storžkih ter pridelek alfa kislin v poskusu v letu 2009

	Yield (kg/ha DM)	Yield (kg/plant DM)	Yield (kg/string DM)	Alpha acid content (% DM)	Alpha acid yield (kg/ha)	Alpha acid yield (kg/string)	Alpha acid yield (kg/ plant)	Nitrate content in hop cones (mg/100 g DM)
1	1883 a*	0.69 a	0.29 a	3.7 a	70 a	0.011 a	0.025 a	523 a
2	1248 b	0.39 b	0.17 b	3.4 a	42 c	0.006 c	0.013 c	18 b
3	1292 b	0.46 b	0.18 b	3.5 a	47 bc	0.007 bc	0.016 bc	9 b
4	1971 a	0.69 a	0.30 a	3.2 a	64 ab	0.010 ab	0.023 ab	527 a
5	1077 b	0.35 b	0.16 b	3.5 a	38 c	0.006 c	0.012 c	25 b

*The same letter in a column indicates that there is no significant difference between treatments with regard to Duncan multiple test (p=0.05)
*Enaka črka v stolpcu pomeni, da med obravnavanjema ni statistično značilne razlike (Duncanov test mnogoterih primerjav, p=0,05)

When we compared treatments 3 and 5, we observed that additional 25 l/ha of Mineral compared to 50 l/ha had a positive effect on the hop yield (by 215 kg/ha) in the production where the use of mineral N fertilization and PPP tried to be avoided although the differences in the yield could not be statistically confirmed (Table 6).

There were no significant differences among treatments in alpha acid content in hop cones (Table 6). There were also no significant differences in nitrate content among treatments where fertilization with N was performed (treatments 1 and 4) and where fertilization without N was performed (treatments 2, 3 and 5; Table 6).

4 CONCLUSIONS

It was found that if we want to achieve the expected yield in the season with high precipitation in June, which is the time of the fastest growth, nitrogen fertilization is obligatory on the investigated type of the soil. A significantly lower yield was achieved with treatments where no mineral N was applied during the growth season. In spite of watering and spraying with '*Mineral'* the yield decreased by 635 kg/ha in the absence of N fertilization, namely. The same was established for the previous season (2008) with high precipitation in July [4] although not at such extent.

While in 2008 no positive effect of '*Mineral'* inclusion (watering and spraying) on the hop yield and alpha acid yield was recorded in conventional production of Celeia cultivar, it was established in 2009 that '*Mineral'* inclusion had a positive effect on the yield (88 kg/ha dry matter of hop cones), but the differences could not be statistically confirmed.

Production of hops only with '*Mineral'* watering and spraying, without PPP and mineral fertilizers failed in 2009 because of the outbreak of hop downy mildew – primary infection was strong at the start of the growing season. Lots of spikes appeared at the beginning of May, so it was estimated that at the time further production would probably not be possible without PPP use. After Al-fosetyl spraying there was no such need any more and finally hop was produced with reduced PPP application on a large scale, but as a result the yield was also

lower. Further investigations into the reduced PPP use and its effect on plants will continue in the next season.

If pest pressure is too high (depending on weather conditions and other factors in a particular year), only the use of '*Mineral'* products is not enough. When the use of PPP is tried to be avoided, observations should be performed on a regular basis and swift actions (application of PPP) should be taken in case of higher pest pressure.

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