PRP PRODUCTS IN HOP PRODUCTION – IMPACT ON SOIL AND YIELD

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Abstract

The aim of the research was to investigate the long-term impact of PRP products on soil and the yield of hops, and to investigate its quality compared to conventional PK fertilisation. The experiment was conducted as a block trial in three replications on the experimental field of Slovenian Institute for Hop Research and Brewing in 2006. Results were collected from 2006 to 2011. In the control (PK), conventional fertilization by P and K according to the soil analysis was performed; no foliar fertilisation was included. At the treatments 200-PRP and 400-PRP, no P and K fertilization was performed; 200 kg/ha and 400 kg/ha yearly PRP SOL was applied, respectively; 2 l/ha of foliar PRP EBV were spayed four times in the season. In 2010, higher porosity and higher biological activity, deeply developed (over 80 cm) and decreasing from the top to the bottom of the soil, was detected at the 400-PRP treatment compared to the PK treatment. At the PK tretatment, the root system was developed until 45 cm; at the 400-PRP treatment until 1.3 m. At the depth of 25 cm, a compact layer of white-coloured soil was detected at PK, while not at the 400-PRP treatment. The significant impact of the 400-PRP treatment on the yield of hops and its quality was not detected until 2011.

Key words: hops, *Humulus lupulus* L., PRP SOL, PRP EBV, yield, alpha acid content, soil

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PROIZVODI PRP V PRIDELAVI HMELJA – VPLIV NA TLA IN PRIDELEK

Izvleček

Cilj raziskave je bil raziskati dolgoročni vpliv proizvodov PRP na tla in pridelek ter kakovost hmelja v primerjavi s konvencionalnim gnojenjem s PK. Poskus je bil postavljen kot bločni poljski poskus v treh ponovitvah na eksperimentalnem polju Inštituta za hmeljarstvo in pivovarstvo Slovenije v letu 2006. Predstavljeni so rezultati med letoma 2006 in 2011. Pri kontroli (PK) smo konvencionalno gnojili s P in K glede na rezultate analiz tal, foliarnih gnojil nismo uporabljali. Pri obravnavanjih 200 PRP in 400 PRP smo letno potrosili po 200 oziroma 400 kg/ha PRP SOL in štirikrat v sezoni škropili s 2 l/ha PRP EBV. V letu 2010 smo zasledili večjo poroznost in večjo biološko aktivnost v tleh pri 400 PRP v primerjavi s PK. Biološka aktivnost je bila globlje v tleh (do globine 80 cm), s tem da se je od vrha proti globini zmanjševala. Pri PK je bil zaznan koreninski sistem do globine 45 cm, pri 400 PRP do globine 1,3 m. Na globini 25 cm je bilo zaslediti zbit sloj bele barve pri PK, pri 400 PRP tega ni bilo zaslediti. Kljub razlikam v tleh pa ni bilo statistično značilnega vpliva proizvodov PRP na pridelek hmelja in njegovo kakovost.

Ključne besede: hmelj, *Humulus lupulus* L., PRP SOL, PRP EBV, pridelek, vsebnost alfa kislin, tla

1 INTRODUCTION

In Slovenia, hops are growing on approximately 1500 ha, mainly in the gravelly soil along the river Savinja, which is often shallow and skeletal (Knapič in Simončič, 2007). Due to changing climatic conditions, agrotechniques in such conditions should be adjusted in a way so that they will be efficient, sustainable and focused on the principles of environmental protection. Among these measures, improving soil characteristics is very important.

The aim of the research was to investigate the long-term impact of PRP products on soil and the yield of hops, and its quality compared to conventional phosphorus (P) and potassium (K) fertilisation.

2 MATERIAL AND METHODS

2.1 Experiment layout

The experiment was conducted as a block trial in three replications on the experimental field of Slovenian Institute of Hop Research and Brewing on 3000 m^2 in 2006. The experiment was continued at the same plots until 2011. The size of one plot was 350 m^2.

The experiment was conducted in a hop field on eutric brown soil with sandy-gravel, middle deep, loam-clay loam texture, with common soil content of P and K for hop gardens in Slovenia (P_2O_5 content in class D [33.0 mg/100 g DM soil], K_2O content in class C [29.0 mg/100 g DM soil], 2.5% organic matter). The research was done with cultivar Hallertauer Magnum.

Treatments:

PK: Control – conventional fertilization by P and K according to the soil analysis; no foliar fertilisation.

200 PRP: No P and K fertilization; 200 kg/ha yearly PRP SOL in spring or autumn plus 2 l/ha of foliar PRP EBV four times in the season; in 2006, 2007 and 2008 at each second foliar treatment with fungicides, first time straight after winding up sprouts; in 2009 and 2011 after winding up sprouts (May 2), intensive growth (June 10), beginning of flowering (June 28) and at cones development (July 19); in 2010 no use.

400 PRP: No P and K fertilization; 400 kg/ha yearly PRP SOL in spring or autumn plus 2 l/ha of foliar PRP EBV the same time as at the treatment 200 PRP.

All the other agrotechnical arrangements (except P and K fertilisation) were the same for all plots according to good agricultural practises. Spraying was performed according to the spraying program. Nitrogen fertilisation was performed in three splits (50 kg/ha N + 80 kg/ha N + 50 kg/ha N as ammonium nitrate; 20 May, 10 June, 5 to 10 July, respectively). There was no other fertilisation except delineated.

2.2 Tested variety and fertilization products

Cultivar Hallertauer Magnum is a product of the Hop Research Centre in Hüll with high yields and strong growth. It is a high alpha variety, expressing medium resistance to Verticillium wilt (*Verticillium albo-atrum*; lethal pathotype PG2), high resistance to downy mildew (*Pseudoperonospora humuli*) and susceptibility to powdery mildew (*Sphaerotheca humuli*). It is a medium-late to late variety with good storage stability and average yield of 2000 kg/ha (CMA catalogue, 2008).

PRP SOL is a pellet made up of a matrix of calcium and magnesium carbonates and technological Mineral Inducer Process (MIP) additives (iron, zinc, boron, sodium, manganese, etc.), agglomerated by the soluble plant-based binder lignosulphonate. PRP SOL is expected to effect the functioning of microbial communities in the soil and the diversification of the profile of enzymatic activities. It should impact all the biological, physical and chemical parameters of the soil ecosystem.

PRP EBV is a physio-stimulant of the plants' vital functions, based on a mineral nutritive solution (sodium, magnesium, sulphur, manganese, boron etc.). PRP EBV is the most efficient when applied as close as possible to key physiological stages and episodes of physical, chemical or climatic stress. In these conditions, PRP EBV is expected to develop the expression of the plant's genetic potential.

2.3 Measurements

In the research, the following characteristics were detected and measured:

- 2006: yield, alpha acid content in hop cones, accessible P and K in the soil after harvest;
- 2007 and 2008: yield and alpha acid content in hop cones;
- 2009: soil analysis in March and after harvest, Nmin in soil (on May 20, July 1 and after harvest), yield, and alpha acid, nitrate and oil content in hop cones;
- 2010: 1.5 m-deep soil profile was dug in order to measure root depth and density, quality of the organic matter by soil layers and soil biological activity;
- 2011: pH of the soil and plant-available quantity of P and K in spring, yield and alpha acid content in hop cones.

Growth and development was observed one to two times a week, plot by plot. Average height of plants per plot was measured and growth stage per plot was noted.

Analyses of pH and accessible P and K in soil were done on samples of the upper layer of the soil (0-25 cm). Soil analyses of pH and available nutrient content were performed according to Al analyse (pH, P_2O5, K_2O); Nmin in soil according to DIN/EN (1998).

In summer 2010, soil profiles were dug at plot PK and plot 400 PRP in the inner block. Analyses of soil on soil profiles were done according to Guide Méthodologique du profil cultural (Manichon and Gautronneau, 1997).

For the yield evaluation, the middle two rows of hops were harvested (90 m^2), number of plants and number of strings per plot were counted and length of plots was measured. The hops were manually harvested plot by plot in the field; cones were harvested by harvester Wolf WS 2000 afterwards, each year at the time of technological maturity. Yield per plot was weighted and samples of cones for moisture content and other analyses were taken.

Determination of the moisture, alpha-acid and essential oils content was performed using standard Analytica-EBC methods 7.2, 7.7, 7.10 and 7.12 (Analytica-EBC 2007). Nitrate content in hop cones was measured according to DIN/EN 12014-7:1998 method.

Results were statistically processed by the computer programs Excel and Statgraphics; differences among treatments were detected by Duncan multiple range test ($p < 0.05$).

2.4 Weather conditions

The average temperature from the beginning of April to the end of August 2006 (growth season) was 17.2° C, there was 670 mm of precipitation. There were relatively low temperatures in spring and at the beginning of August 2006, and very high temperatures in July. Spring was wet and cold, and there was a large amount of precipitation in the beginning of June.

The average temperature in growth season 2007 was 18.2° C, which is almost two degrees higher than the long-term average. In addition to above-average temperatures, there were high temperature oscillations. There was 473 mm of precipitation, 116 mm less than the long-term average.

The average temperature in the growth season of 2008 was 16.4° C, which is one degree higher than the long-term average. In the last ten days of June, extremely high temperatures were recorded. There was 713 mm of precipitation in the growth season, which is 124 mm more than the long-term average. Many times it rained in showers and storms that were accompanied by hail.

The average temperature in the growth season of 2009 was 18.1° C, there was 540 mm of precipitation. In May 2009 there were relatively high temperatures, which decreased suddenly at the end of the month. Compared to the long-term average, there was more precipitation in June (174 mm) and at the beginning of July. At the beginning of August there were relatively high temperatures.

The average temperature in the growth season of 2010 was 17.7° C, there was 398 mm of precipitation. In all the decades of hops growing seasons, in 2010 (until the end of July) there was less rainfall compared to the long-term average and temperatures were above average.

Almost throughout the growth season of 2011, higher temperatures than the long-term average were recorded. There was 413 mm of rainfall, which is 173 mm less compared to the 40-year average. Precipitation quantity in almost all decades was lower compared to the long-term average.

3 RESULTS AND DISCUSSION

3.1 Growth and development

In the first year (2006), growth of plants was faster in June in the 400-PRP treatment compared to the plants of the other two treatments. Also, the final height was the highest at the 400-PRP treatment (plant height was approximately 6.5 m at the treatments PK and 200-PRP and more than 7 m at the 400-PRP treatment). Treatments with PRP (200-PRP and 400-PRP) started to bloom four days sooner compared to treatment PK, while all three treatments completed the stage of blooming at the same time. PRP fertilization caused hop cones to start to ripen sooner compared to the PK treatment (and sooner at the higher PRP rate, which was 400 PRP). At the time of harvest, on 4 September 2006, plants at all variants were mature. Because 400 PRP showed difference in growth compared to the other two treatments in June and not in the yield, it was suggested to perform PRP SOL application in autumn for the next season, not just in the spring.

Plant growth and development was measured again in 2009. At that time there were no important differences in plant growth and development among treatments. Plants of the treatment 400 PRP were approximately 20 cm higher compared to the plants of the treatments PK and 200 PRP during May and June. At the end of the season, all plants were at the top of the hop trellis.

3.2 Soil analyses

After harvest in 2006, accessible P_2O_5 content in soil stayed in class D and accessible K_2O content stayed in class C, as it was in the spring that year (Table 1). At the end of the growth season of 2006, lower pH values were detected at all three treatments compared to spring. There was no detectable difference among treatments.

In 2009 at the start of the season and after the harvest, plant-available nutrient content, total nutrient content and pH value were analysed again (Table 2). At harvest, a lower pH value was detected in the soil of treatment 400 PRP compared to PK and 200 PRP. There were no big differences among treatments in the total nutrients content, with exception of total quantity of Ca, which was higher at the treatment 200 PRP compared to PK and 400 PRP. At PK, where P and K applications were made each spring, there was a higher content of plant-available P and K in the upper layer of the soil (0-25 cm) after harvest compared to 200 PRP and 400 PRP. Plant available Mg and CaO were higher at 200 PRP compared to PK and 400 PRP.

Table 1: P_2O_5, K_2O content and pH value in the upper layer of the soil (0-25 cm) at the end of the 2006 season with regard to the treatment
Preglednica 1: Vsebnost P_2O_5 in K_2O v zgornjem sloju tal (0-25 cm) in vrednost pH tal po koncu sezone v letu 2006 glede na obravnavanje

Depth (cm)	Treatment	pH in KCl	pH in Ca-acetat	P_2O_5* mg/100 g soil	K_2O* mg/100 g soil
0-25	PK/1	5.0	6.4	22.0 C	24.5 C
0-25	PK/2	5.2	6.4	28.0 D	30.1 C
0-25	PK/3	5.8	6.6	45.0 E	38.7 D
0-25	200/1	5.1	6.4	23.0 C	23.2 C
0-25	200/2	5.2	6.5	26.0 D	24.9 C
0-25	200/3	5.4	6.5	34.0 D	24.1 C
0-25	400/1	5.3	6.4	28.0 D	23.1 C
0-25	400/2	5.4	6.5	30.0 D	24.9 C
0-25	400/3	5.3	6.5	26.0 D	20.2 C

*C: well supplied, D: over supplied, E: extreme supplied

Table 2: Plant-available content of nutrients in the upper layer of the soil (0-25 cm), total nutrient content and pH value after the harvest in 2009 (in soil dry matter)
Preglednica 2: Rastlinam dostopna količina hranil v zgornjem sloju tal (0-25 cm), skupna količina hranil in vrednost pH tal po obiranju v letu 2009 (na suho snov v tleh)

	Unit	PK	200 PRP	400 PRP
pH v KCl	-	6.2	6.6	5.7
Total P	%	0.10	0.10	0.09
Total K	%	0.23	0.23	0.20
Total Mg	%	0.40	0.44	0.38
Total N	%	0.17	0.17	0.18
Total Ca	%	0.45	0.75	0.41
Plant available P_2O_5	mg/100 g	33.5	27.5	26.4
Plant available K_2O	mg/100 g	25.4	17.4	13.3
Plant available Mg	mg/100 g	21.6	31.6	20.9
Plant available CaO	%	0.59	0.84	0.54

At the start of the 2011 season, compared to the data from 2006, plant-available phosphorus content in soil stayed at the same level at treatments 200 PRP and 400 PRP and increased a bit at the treatment PK (Table 3). Plant-available potassium content decreased at all treatments, more at the treatments with PRP.

Table 3: Plant-available content of P and K in soil (0-25 cm) and pH value in spring 2011 with regard to treatment
Preglednica 3: Rastlinam dostopna količina hranil P in K v tleh (0-25 cm) in vrednost pH tal spomladi 2011 glede na obravnavanje

	Enota / *Unit*	PK	2 PRP	3 PRP
pH v KCl	-	6.3	6.5	6.2
Plant available P_2O_5	mg/100 g	38	35	34
Plant available K_2O	mg/100 g	26	23	21

*At all plots soil is well-supplied by K_2O (class C) and oversupplied by P_2O_5 (class D).

3.3 Nmin in soil

Nmin in soil was measured in 2009. There was a relatively low quantity of plant-available nitrogen in the upper layer of soil (0-25 cm) especially in the beginning of July, before third N fertilization. The explanation is that the experiment was conducted on shallow soil with a relatively high content of particles bigger than 2 mm (skeleton), and there was a high quantity of precipitation in June. The highest Nmin content in the beginning of July was at the 200-PRP treatment.

After harvest there was less than 50 kg/ha Nmin content in the upper layer of soil (0-25 cm) at all treatments (Figure 1).

3.4 Soil profile measurements

The development of the root system is connected with the disponibility of oxygen. The strength and deepness of the root system is a good indicator of the evolution of the soil porosity created by the biological activity (Weill, 2008). In the control plot (PK), the root system was developed up to 45 cm, and on the 400-PRP plot the depth of the roots was much greater (up to 1.3 m) (Table 4). Deep development of the root system ensures access to water and minerals to plants directly from the soil. At a depth of 25 cm, a white-coloured, compacted layer of soil was detected at the PK treatment. Analyses confirmed it was calcium carbonate. There was no such layer detected at the 400-PRP treatment.

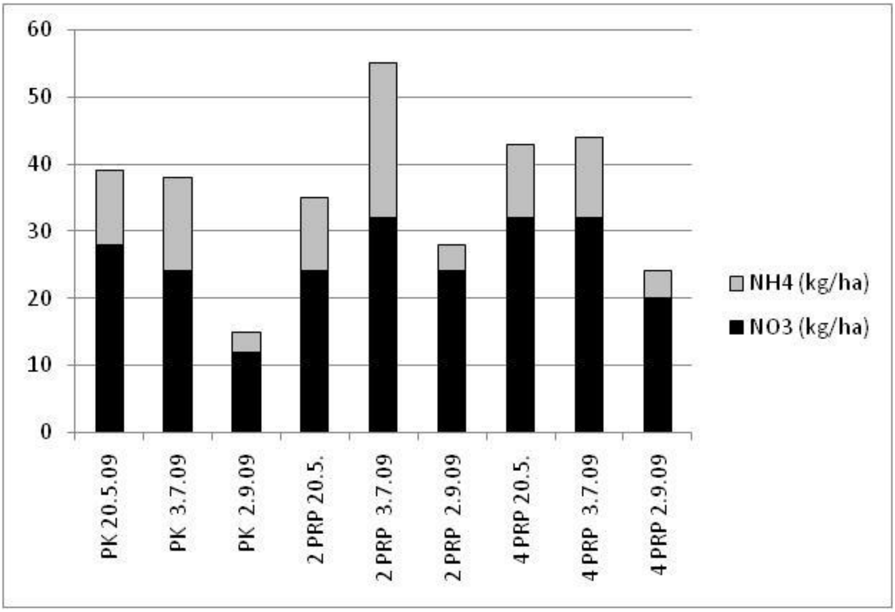

Figure 1: Plant-available N (ammonium and nitrate) quantity in top soil (0-25 cm) with regard to sampling date (May 15, July 3, September 2) in the year 2009 and treatment (PK, 200 PRP, 400 PRP)

Slika 1: Količina rastlinam dostopnega dušika (amonijska in nitratna oblika) v zgornjih 25 cm tal glede na datum vzorčenja v letu 2009 (15. maj, 3. julij in 2. september) in obravnavanje (PK, 200 PRP, 400 PRP)

Table 4: Depth of main roots, biological activity and quality of the organic matter on the control plot (PK) and on 400 PRP plot in 2010

Preglednica 4: Globina koreninskega sistema, biološka aktivnost in kakovost organske snovi v tleh kontrolne parcele (PK) in parcele 400 PRP v letu 2010

	Depth of roots		Biological activity		Quality of the organic matter	
Soil layer	PK	400 PRP	PK	400 PRP	PK	400 PRP
25-0 cm	+++	-	++	+++	+	+++
0-50 cm	++	+++	+	++	-	++
50-80 cm	-	++	-	++	-	+
80 cm and deeper	-	++	-	+	-	-
The deepest roots	45 cm	1.3 m				

Legend: - : lacking, + : low level, ++ : average level, +++ : high level

On the control plot (PK), biological activity was detected in a medium level in the upper 50 cm of soil including the mound. On the 400 PRP plot biological activity was deeply developed (over 80cm), decreasing from the top to the bottom of the soil (Table 4).

The better the quality of the organic matter, the higher possibility it has to be oxidized (Mustin, 1987). On the control plot, the quality of the organic matter was low even in the mound (Table 4). On the 400-PRP plot, the quality of the organic matter was higher. It was decreasing from the top to a depth of 80 cm (Table 4).

3.5 Yield and alpha acid content

In 2006 there was not a significant difference between the yield of hop cones and the yield of alpha acids of the treatments PK and 400-PRP (Table 5). 200-PRP treatment reached a statistically lower yield compared to the treatment PK, what could be the consequence of agrotechnique before the conduction of the experiment. There was not a statistically significant difference in alpha acid content among treatments. Consequently, the treatment 200 PRP reached a statistically lower yield of alpha acid per hectare compared to the treatment PK, even if the alpha acid content in hop cones was indicated to be higher.

In the second season (2007), the higher yield was —contrary to the first season— indicated at the 200-PRP tretament, but the differences among treatments could not be statistically confirmed (Table 5).

There were no significant differences among treatments in the yield of cones, yield of alpha acids and alpha acid content in 2008 and 2009 (Table 6).

Table 5: Yield of hop cones, alpha acid content and alpha acid yield in 2006 and 2007

Preglednica 5: Pridelek hmelja, vsebnost alfa kislin in pridelek alfa kislin v letih 2006 in 2007

	2006			2007		
Treat-ment	Yield (kg/ha DM)	Alpha acid (% in DM)	Alpha acid (kg/ha)	Yield (kg/ha DM)	Alpha acid (% in DM)	Alpha acid (kg/ha)
PK	1903 b	11.8 a	223 b	949 a*	11,2 a	104 a
200 PRP	1472 a*	12.2 a	181 a	1209 a	10,7 a	129 a
400 PRP	1672 ab	11.6 a	194 ab	1077 a	11,8 a	127 a

* The same letter in a column indicates that there is no significant difference between treatments according to Duncan test (p=0.05)

Table 6: Yield of hop cones, alpha acid content and alpha acid yield in 2008 and 2009
Preglednica 6: Pridelek hmelja, vsebnost alfa kislin in pridelek alfa kislin v letih 2008 in 2009

	2008			2009		
Treat-ment	Yield (kg/ha DM)	Alpha acid (% in DM)	Alpha acid (kg/ha)	Yield (kg/ha DM)	Alpha acid (% in DM)	Alpha acid (kg/ha)
PK	2228 a*	14.6 a	328 a	1599 a	13.5 a	217 a
200 PRP	2107 a	15.0 a	315 a	1385 a	12.0 a	167 a
400 PRP	1994 a	14.3 a	285 a	1373 a	12.4 a	171 a

* The same letter in a column indicates that there is no significant difference between treatments according to Duncan test (p=0.05)

In spite of differences detected in the soil in summer 2010, there were no significant differences in the yield of hops and alpha acid content in hop cones in 2011 among treatments (Table 7). We assume that the low precipitation amount in summer months had an impact on lower absorption of nutrients from soil at all treatments.

Table 7: Yield of hop cones, alpha acid content and alpha acid yield in 2011
Preglednica 7: Pridelek hmelja, vsebnost alfa kislin in pridelek alfa kislin v letu 2011

	2011		
Treat-ment	Yield (kg/ha DM)	Alpha acid (% in DM)	Alpha acid (kg/ha)
PK	1611 a	11.3 a	182 a
200 PRP	1542 a	10.9 a	163 a
400 PRP	1633 a	11.3 a	183 a

3.6 Nitrate and essential oil content in hop cones

There were no significant differences among treatments in nitrate content or in oil content in cones in 2009 (Table 8).

Table 8: Nitrate and essential oil content in hop cones in 2009
Preglednica 8: Vsebnost nitatov in olj v storžkih v letu 2009

	Nitrate content (mg/100 g DM)	Essential oil content (ml/100 g DM)
PK	574 a*	3.64 a
200 PRP	899 a	2.97 a
400 PRP	836 a	3.42 a

* The same letter in a column indicates that there is no significant difference between treatments (p=0.05).

4 CONCLUSIONS

The use of PRP products at the 400-PRP treatment increased the biological activity of soil that had been developed and at the same time increased the porosity of the soil. This modification of the soil structure from 2006 to 2011 encouraged oxygen and roots to penetrate deeper, so the capacity of the plant to resist different stresses is expected to be increased.

The significant impact of 400 PRP on the yield of hops and its quality was not detected until 2011. The impact was not expected in the first years, because hops are a perennial plant, and 2011 was dry during the summer months, which probably prevented the absorption of nutrients at all treatments.

The investigation should continue in the next seasons in order to accompany hop yield and alpha acid content in seasons with different precipitation distribution. As detected visually and with measurements in soil profiles in 2010, plants should be more able to absorb nutrients and water from deeper layers when using the 400-PRP treatment compared to control treatment (PK).

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