EFFECT OF THE STABILIZED NITROGEN FERTILIZER ON THE HOP YIELD AND ITS QUALITY COMPARED TO CALCIUM AMONNITRATE

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ABSTRACT

Of all mineral nutrients N is quantitatively the most important for plant growth, but N recovery from mineral fertilizers is relatively low. Previous investigations show that 3,4-dimethylpyrazol phosphate application with ammonium sulphate nitrate as Entec 26 has reduced N losses due to nitrate leaching and N_2O emissions and had a positive effect on the yield. The results of Aurora hop cultivar presented in the experiment indicated that fertilization with Entec 26 in one split was comparable to conventional fertilization with calcium amonnitrate (KAN) in three splits as far as the yield, alpha acid content, alpha acid yield and nitrate content in hop cones in seasons 2008 and 2009 are concerned.

Key words: hops, *Humulus lupulus* L., nitrogen, fertilization, Entec 26

VPLIV DOGNOJEVANJA HMELJA Z GONJILOM S STABILIZIRANIM DUŠIKOM V PRIMERJAVI S KALCIJEVIM AMONNITRATOM NA PRIDELEK HMELJA IN NJEGOVO KAKOVOST

IZVLEČEK

Med vsemi hranili je dušik najpomembnejši za rast rastlin, vendar je izkoristek tega hranila iz mineralnih gnojil relativno majhen. Dosedanje raziskave so pokazale, da uporaba 3,4-dimetilpirazol fosfata kot zaviralca bakterijske pretvorbe amonijske oblike dušika v nitratno zmanjša izgube dušika zaradi izpiranja nitratov in emisij N_2O ter pozitivno vpliva na pridelek. Rezultati predstavljene raziskave kažejo, da je bilo v preučevanih letih 2008 in 2009 dognojevanje hmelja cv. Aurora z Entec 26 v enem obroku v primerjavi z dognojevanjem s kalcijevem amonnitratom (KANom) v treh obrokih (pri istem odmerku N) primerljivo po pridelku, vsebnosti alfa kislin, pridelku alfa kislin in vsebnosti nitratov v storžkih.

Ključne besede: hmelj, *Humulus lupulus* L., dušik, gnojenje, Entec 26

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1 INTRODUCTION

Of all mineral nutrients nitrogen (N) is quantitatively the most important for plant growth. N uptake from the soil is mainly in the form of ammonium and nitrate, and is regulated not only by the chemical and spatial availability of N in the soil, but also by the activity and number of transport systems at the cellular level, transport from the roots to the shoot, and utilization of growth and storage [3].

Although N recovery from mineral fertilizers is relatively low, especially in the production of rice, cotton and sugarcane where high mineral N rates are experienced and at the same time N losses are high, many farmers tolerate it, and in a good economic situation higher N rates are practised and that increases N losses due to denitrification and volatization [3].

Nitrification inhibitors like 3,4-dimethylpyrazol phosphate (DMPP) are compounds that delay the bacterial oxidation of ammonia to nitrite in the soil (first step of nitrification) for a certain period of time by depressing the activity of *Nitrosomonas* bacteria in the soil [13]. Application of nitrification inhibitors with several ammonium-based fertilizers resulted in a decrease of N_2O emissions [5,14,6]. Investigations showed that DMPP application with ammonium sulphate nitrate (ASN) as Entec 26 has reduced N losses due to nitrate leaching [8,4] and N_2O emissions [16,12].

In the experiment by Paschold et al. [15] on the plots fertilized with Entec 26 the total number of shoots and the number of asparagus spears with diameter >10 mm on the soil surface increased. In 2001 no significant yield differences with a positive trend for Entec 26 were found in the years following. In comparison with ASN the application of Entec 26 led to significant yield increases in 2004. The results of the study by Kołota et al. [11] showed that Entec 26 was an equally valuable source of N for red beet as ammonium nitrate and calcium nitrate and more efficient than ammonium sulphate. In experiment with celeriac, plants supplied with this fertilizer in split doses overyielded those receiving the same amounts of ammonium nitrate. An important advantageous effect of Entec 26 use was a considerable reduction of nitrates accumulation in red beet and in celeriac roots. Results of the study by Kołota and Adamczewska–Sowińska [10] showed that Entec 26 was a better source of nitrogen than ammonium nitrate, providing higher yield of marketable heads and lower nitrate contents in plants of cabbage at harvest. In the experiment by Menéndez et al. [13] it was concluded that DMPP is an efficient nitrification inhibitor that reduces N_2O and NO emissions from grasslands.

The aim of the experiment was to investigate the effect of N fertilization in the form of Entec 26 in one split compared to fertilization with KAN in three splits on the hop yield and its quality. Plant growth, growth stages, Nmin content in soil, yield, alpha content in hop cones, alpha acid yield and nitrate content in hop cones were observed.

2 MATERIAL AND METHODS

2.1 Material

In the experiment Entec 26 was used as a source of N (26% total N; 7,5% nitrate N, 18,5% ammonium N) compared to calcium amonnitrate (KAN) at control treatment. Entec 26 is a granulated mineral fertilizer with stabilized ammonium form of N and water soluble sulphur (ammonium sulphate: 26+0+0 (+13S)) which differs from other conventional products in DMPP additive. N is made available to plants gradually; the whole amount is loosened in the period of 4 to 10 weeks in accordance with the temperature and moisture of the soil. This way we avoid frequent crossings of the field in order to perform N fertilization because higher doses can be used at a time. The number of doses can be reduced by one or two. Because N losses are reduced, 20-30% lower N rates can be implemented compared to fertilizers with no DMPP stabilizer [9].

2.2 Field experiment and evaluation

The experiment was conducted as a block trial in three replications in the experimental field of Slovenian Institute of Hop Research and Brewing in 2008 and 2009 with hop cultivar Aurora which is planted on approximately 60% of Slovenian hop fields. The size of one plot was 200 m^2. There were two treatments:

Control: Control treatment; conventional fertilization with N in the form of KAN in three splits (50 kg/ha N 20 May + 70 kg/ha N 15 June + 50 kg/ha N 10 July).

ENTEC: Fertilization with N in the form of Entec 26 in one split (170 kg/ha N on 20 May).

The rest of the agrotechnique was the same for all plots and performed in accordance with good agricultural practice. Phosphorus and potassium fertilization was performed in accordance with the soil analysis. No foliar fertilizers were used. Plant protection products were used in accordance with the spraying programme.

In the time of technological maturity the inner two rows on each parcel were evaluated; the number of plants and strings per plot was counted, the plot was measured, hop cone yield was weighed, samples were taken for analysis of moisture, alpha acids and nitrate content. Moisture content in hop cones was determined with Analytica-EBC (1998) method [1], alpha acid content with Analytica-EBC (2000) [2] method, and nitrate content with DIN/EN (1998) [7] method.

The results obtained for yield, alpha acid content, alpha acid yield and nitrate content were statistically processed in Excel and Statgraphics computer programs, and the differences among treatments were determined with Duncan multiple range test ($p<0.05$) for each year separately (as a block trial), because the experiment was not carried out in the same hop field in both years.

2.3 Soil analysis

The experiment was conducted in a hop field with eutric brown soil on sandy – gravel, middle deep, loam–clay texture. In the upper 25 cm the soil was plentifully supplied with plant available phosphorus (43.0 mg P_2O_5/100 g soil; Al method) and well supplied with plant available potassium (27.4 mg K_2O/100 g soil; Al method)), pH value was 6,4 (pH in KCl).

2.4 Weather conditions

In 2008 season there were 713 mm of precipitation, which is 124 mm more than the long term average (Figure 1). With regard to location and time, precipitation was not evenly distributed. There were lots of showers and storms with hail which occurred already in May. From June to August there was 83% of all precipitation in the growth season. There was only 47 mm of precipitation in May and 228 mm in June (Figure 1). All months were warmer compared to the long term average, except the second decade of June which was colder. In the last decade of June extremely high temperatures for the time of the year were recorded; maximum daily temperatures exceeded 30^{o}C. Average temperatures were higher by 4.6^{o}C compared to the long term average. Warm weather continued in July, but maximum daily temperatures exceeded 30^{o}C four times only.

In 2009 the temperatures were relatively high in May and decreased suddenly at the end of the month (Figure 1). This resulted in non-uniform and long flowering and consequently in non-uniform ripening of Aurora cultivar. There were big differences among hop fields as well as among plants in the same hop field. Even on the same plant at the same time we found cones that were over-mature, immature and mature. 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.

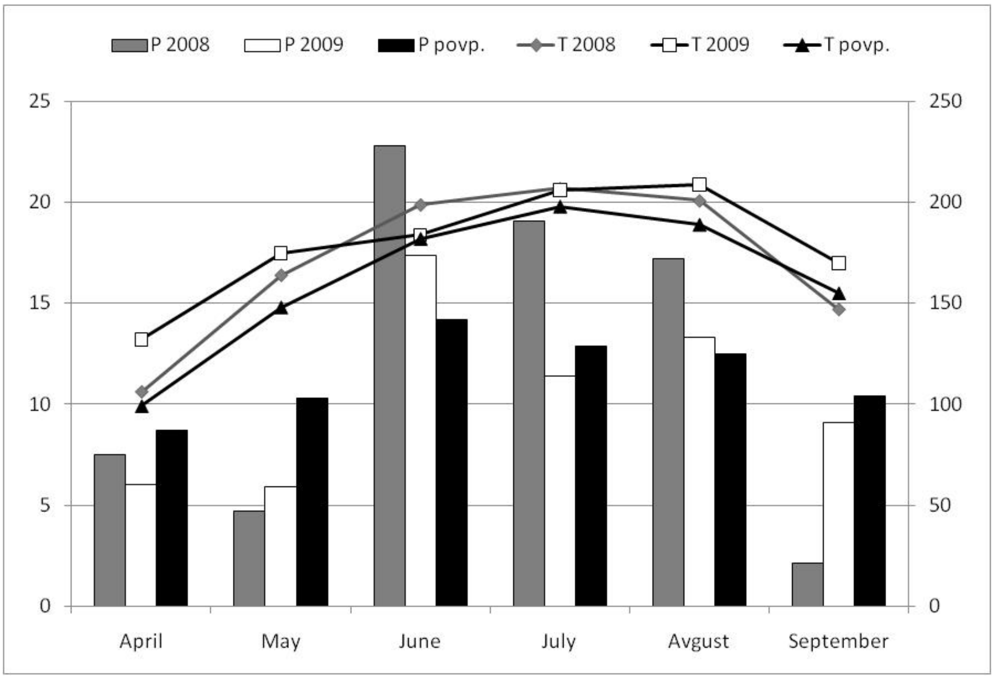

Figure 1: Weather conditions in the growth season of hops in 2008 and 2009 compared to the long term average; P = precipitation amount (mm), P povp. = long term precipitation amount (mm), T = decade average temperature (^{o}C), T povp. = long term average decade temperature (^{o}C)
Slika 1: Vremenske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

2.5 Plant growth and growth stages

Plant height was measured once to twice a week in the time of fast growth. At the same time growth stages were determined with regard to treatment.

2.6 Plant available nitrogen (Nmin) content in soil

Three times in the season (in May – before first N application, at the beginning of July, at harvest) soil was analysed for plant available nitrogen (Nmin; NO_3-N and NH_4-N) (in-house method) in the upper layer of soil (0-25 cm) with regard to treatment (all three replications together).

3 RESULTS AND DISCUSSION

3.1 Plant growth and growth stages

There were no significant differences in the plant growth (Figure 2 and Figure 3) and in the appearance of growth stages in both years. On the other hand, different results were reported for other crops (e.g. in the experiment with asparagus done by Paschold [15] differences in the plant growth were recorded).

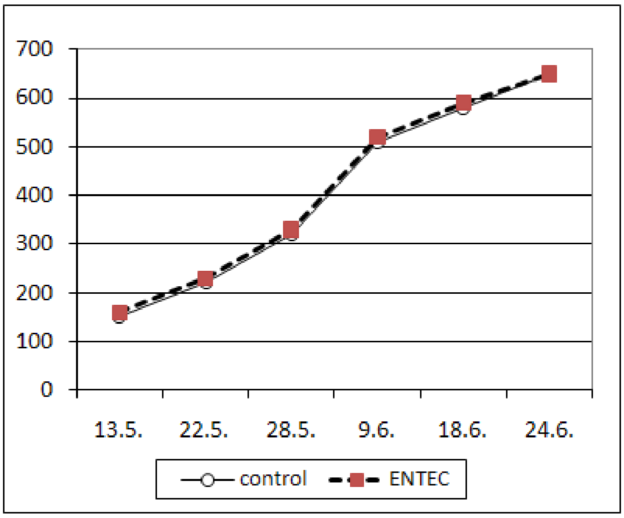

Figure 2: Plant height (cm) with regard to treatment (control, ENTEC) and date in 2008
Slika 2: Višna rastlin (cm) glede na obravnavanje (control, ENTEC) in datum meritve v letu 2008

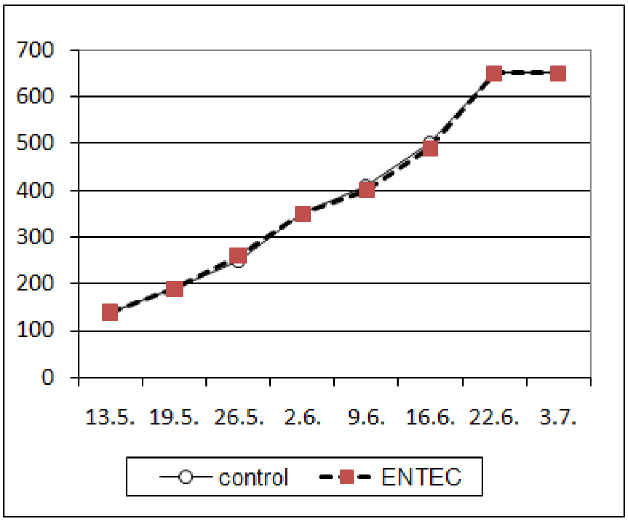

Figure 3: Plant height (cm) with regard to treatment (control, ENTEC) and date in 2009
Slika 3: Višna rastlin (cm) glede na obravnavanje (control, ENTEC) in datum meritve v letu 2009

3.2 Plant available N (Nmin) content in the soil

Nmin (NO_3^- - N and NH_4^+ - N) in the upper layer of the soil (0-25 cm) was between 20 and 40 kg/ha N in May 2008 (Figure 4). At the beginning of July there was an indication that Nmin in the soil was comparable between treatments, but after the harvest a little higher Nmin was detected at treatment with ENTEC compared to control treatment. The results obtained are in agreement with the experiment done with asparagus where the differences in the supply of nitrogen were detected [15].

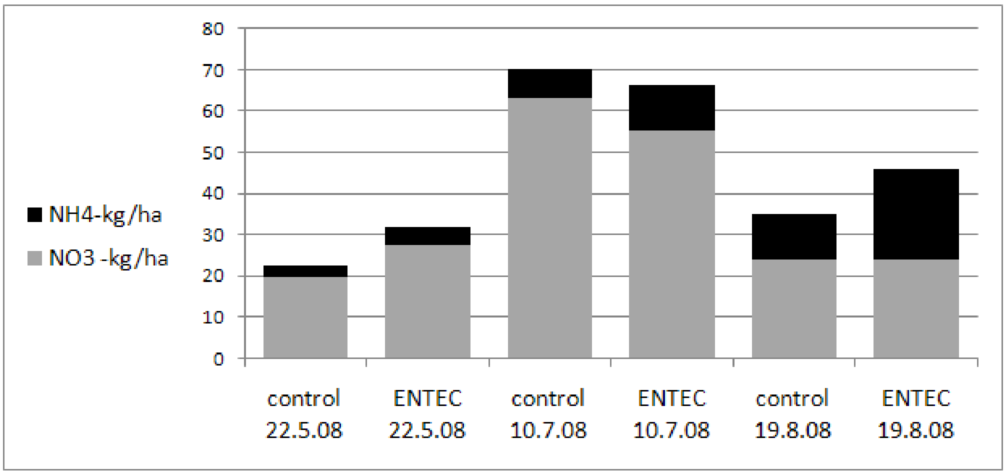

Figure 4: Nmin (NO_3-N and NH_4-N) quantity (kg/ha) in the upper layer of the soil (0-25 cm) with regard to sampling date (22.5.2008, 10.7.2008, 19.8.2008) and treatment (control, ENTEC) in 2008
Slika 4: Količina rastlinam dostopnega dušika (NO_3-N and NH_4-N; kg/ha) v zgornjih 25 cm tal glede na datum vzorčenja (22.5.2008, 10.7.2008, 19.8.2008) in obravnavanje (control, ENTEC) v letu 2008

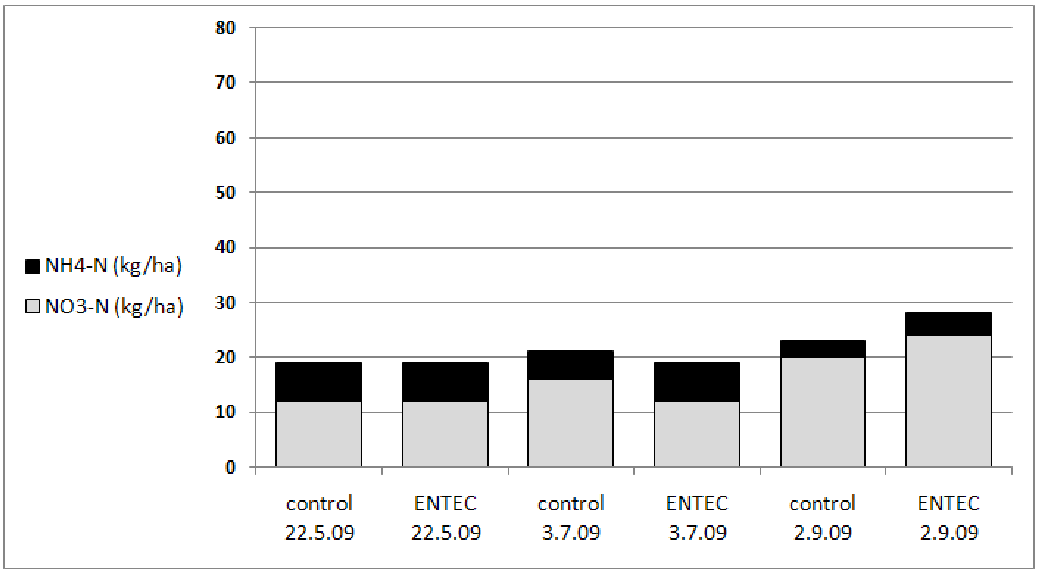

Figure 5: Nmin (NO_3-N and NH_4-N) quantity (kg/ha) in the upper layer of the soil (0-25 cm) with regard to sampling date (22.5.2009, 3.7.2009, 2.9.2009) and treatment (control, ENTEC) in 2009
Slika 5: Količina (kg/ha) rastlinam dostopnega dušika (NO_3-N and NH_4-N, v kg/ha) v zgornjih 25 cm tal glede na datum vzorčenja (22.5.2009, 3.7.2009, 2.9.2009) in obravnavanje (control, ENTEC) v letu 2009

In 2009 Nmin quantity was relatively low at all three samplings (Figure 5). This was probably due to the high amount of precipitation in June (Figure 1), which is the time of fast hop growth and nutrients absorption, and due to the fact that the experiment was carried out in the shallow soil with higher content of skeleton. The differences between the treatments were not recorded.

None of the treatments in both seasons showed higher Nmin quantity in the upper layer of the soil than 50 kg/ha N recorded at harvest.

3.3 Yield, alpha acid content and alpha acid yield

In 2008 there were no significant differences between treatments in the cone yield, alpha acid content and alpha acid yield (Table 1).

Table 1: Cone yield (dry matter - DM) per ha, per plant and per string, alpha acid content in cones (% in DM), alpha acid yield per ha, per plant and per string in 2008
Preglednica 1: Pridelek (kg suhe snovi) storžkov na hektar, na rastlino in na vodilo, vsebnost alfa kislin (% v suhi snovi) in pridelek alfa kislin (kg) v letu 2008

Treatment	Yield (kg/ha)	Yield (kg/plant)	Yield (kg/string)	Alpha acid (% in DM)	Alpha acid yield (kg/ha)	Alpha acid yield (kg/string)	Alpha acid yield (kg/plant)
Control	1771 a*	0.64 a	0.33 a	10.1 a	180 a	0.034 a	0.065 a
ENTEC	1839 a	0.65 a	0.32 a	9.4 a	173 a	0.030 a	0.061 a

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

Table 2: Cone yield (dry matter - DM) per ha, per plant and per string, alpha acid content in cones (%), alpha acid yield per ha, per plant and per string in 2009
Preglednica 2: Pridelek (kg suhe snovi) storžkov na hektar, na rastlino in na vodilo, vsebnost alfa kislin (% v suhi snovi) in pridelek alfa kislin (kg) v letu 2009

Treatment	Yield (kg/ha)	Yield (kg/plant)	Yield (kg/string)	Alpha acid (% in DM)	Alpha acid yield (kg/ha)	Alpha acid yield (kg/string)	Alpha acid yield (kg/plant)
Control	1527 a*	0.47 a	0.20 a	8.4 a	128 a	0.016 a	0.040 a
ENTEC	1376 a	0.45 a	0.19 a	7.8 a	107 a	0.015 a	0.035 a

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

Although lower yield, alpha acid content and alpha acid yield was recorded in 2009 at ENTEC treatment compared to the control (Table 2), the differences could not be statistically confirmed.

Lower yield was recorded in 2009 compared to the previous season probably due to unfavourable weather conditions. High amount of precipitation in June was the cause for less nutrients available in lighter soil in the time of the fastest growth and development; warm May with cooling caused uneven flowering, hot beginning of August had a negative effect on the alpha acid formation.

3.4 Nitrate content in hop cones

In both investigated years there were no significant differences in nitrate content in hop cones between treatments (Table 3). In comparison with 2008, lower nitrate content in 2009 was probably due to weather conditions.

Table 3: Nitrate content in hop cones (mg/100 g DM) with regard to treatment (control, ENTEC) in field experiment in 2008 and 2009
Preglednica 3: Vsebnost nitratov v storžkih (mg/100 g suhe snovi) glede na obravnavanje (control, ENTEC) v poskusu v letih 2008 in 2009

	Nitrate content ($mg\ NO_3^-/100\ g$ DM)	
year	2008	2009
Control	1160 a*	599 a
ENTEC	1098 a	775 a

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

4 CONCLUSION

It was found that the results of Aurora hop cultivar fertilization with Entec 26 in one N split were comparable to conventional fertilization with KAN in three splits as far as the yield, alpha acid content, alpha acid yield and nitrate content in hop cones in seasons 2008 and 2009 are concerned. The result is positive because there was one crossing of the field to perform N fertilization in the case of Entec 26 compared to three crossings in the case of control.

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