INFLUENCE OF ROW DISTANCE, PLANT DENSITY AND NUMBER OF TRAINING BINES ON YIELD AND ALPHA ACID CONTENT IN HOPS (*Humulus lupulus* L.) cv. DANA

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Abstract

The influence of row distance (2.4 m and 2.8 m), plant density (2,800 and 3,200 plants per hectare) and number of traininig bines per string (3, 4, 5) on the yield of hop cones and alpha acids content of cv. Dana was studied during the three years of hop vegetation, since 2007 till 2009. The field experiment was carried out on the experimental field of Slovenian Institute of Hop Research and Brewing in Žalec, designed as a random block field trial in three replications. Hop cultivar Dana is a middle late hop cultivar, bred at the Slovenian Institute of Hop Research and Brewing. It is a representative of so called high alpha hop cultivars. Weather conditions had the highest influence on the yield of hop cones, content of α-acids and α-acids yield. Lower plant density (2,800 plants/ha) would be recommendable in the hop field with 2.4 m row distance and higher plant density (3,200 plants/ha) would be recommendable at 2.8 m row distance in the conditions of the conducted experiment.

Key words: hops, *Humulus lupulus* L., hop cv. Dana, plant density, yield, alpha acids, training

VPLIV MEDVRSTNE RAZDALJE, GOSTOTE RASTLIN IN ŠTEVILA NAVITIH POGANJKOV NA PRIDELEK IN VSEBNOST ALFA KISLIN PRI HMELJU (*Humulus lupulus* L.) SORTE DANA

Izvleček

V letih 2007 do 2009 smo v poljskem bločnem poskusu v treh ponovitvah preučevali vpliv medvrstne razdalje (2,4 m in 2,8 m) in gostote rastlin (2.800 in 3.200 rastlin/ha) ter števila navitih poganjkov (3, 4, 5) na pridelek, pridelek alfa kislin in vsebnost alfa kislin v storžkih sorte Dana. Sorta Dana je žlahtnjena na IHPS, predstavnica sort z višjo vsebnostjo alfa kislin. V polnorodnem nasadu hmelja so imele največji vpliv na preučevane parametre vremenske razmere. Pri medvrstni razdalji 2,4 m je bila bolj priporočljiva manjša gostota rastlin (2.800 rastlin/ha), pri medvrstni razdalji 2,8 m pa zaradi značilno večjega pridelka večja gostota rastlin (3.200 rastlin/ha).

Ključne besede: hmelj, *Humulus lupulus* L., sorta Dana, gostota rastlin, pridelek, alfa kisline, napeljava

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1 INTRODUCTION

Hop breeding program of Slovenian Institute of Hop Research and Brewing was started some 50 years ago. Nowadays, 13 of reached hop cultivars are planted on more than 95 % of Slovenian hop fields. In the comparison with well-known aromatic Slovenian hop cultivars such as Aurora and Celeia, the newest hop cultivar Dana, released in 2007, has primarily bitter characteristics. Two important traits of cv. Dana, such as high content of α-acids and at the same time pleasant aroma, fit the variety into the recent qualitative demands of beer industry.

As for each new released cultivar, agrotechnique needs to be assessed to gain as much as possible from it. Among agro-technological factors plant density and plant spacing impact the yield and its quality at cultivated plants, as well.

Investigations about the impact of plant density and plant spacing on the yield of hops and its quality are not published for hops, while results of the investigations for other cultivated plants showed, for example, that more squared arrangement of plants has more positive impact on the yield compared to more rectangle plant distribution at the same plant density. It was confirmed in the experiment by Čeh at al. [4] for oilseed pumpkins, too. Other investigators report the impact of plant spacing on different parameters of cultivated plants as well [5,6,7].

In the presented paper the impact of plant density, plant spacing and the number of training bines at hops cv. Dana on the yield and its quality is presented.

2 MATERIAL AND METHODS

2.1 Material

The experiment was carried out in the hop field of cv. Dana, a middle late hop cultivar, bred at the Slovenian Institute of Hop Research and Brewing, representative of high alpha varieties. Its cones contain 12.5 % to 19.3 % alpha acids in dry matter. Technological maturity is reached in the last days of August or in the beginning of September. Essential oil content ranges from 3.1 ml/100g to 4.6 % in dry matter, the expected yield is between 1800 kg/ha and 2800 kg/ha. It is middle resistant to downy mildew (*Pseudoperonospora humuli* (Miyabe et Takahashi) G.W. Wilson) and mild form of hop *Verticillium* wilt, low resistant to powdery mildew (*Podosphaera macularis*), botrytis (*Botrytis cinerea*), and lethal form of *Verticillium* wilt (*Verticillium albo-atrum* Reinke et Berthold in *Verticillium dahliae* Klebahn) [8].

2.2 Experiment layout

Field experiment was conducted at the experimental field of Slovenian Institute of Hop Research and Brewing (IHPS) in two hop fields with different row distances (2.4 and 2.8 m) in 2006 and continued at the same plots in 2007 to 2009 as a random block trial in three replications. The size of plots was approximately 200 m^2. There were six treatments, as presented in Table 1, investigated in both hop fields. In 2006 hop plants were planted, measurements were performed in the following years (2007 to 2009).

Table 1: Plant density and number of trained bines in hop fields of cv. Dana with row distances 2.4 m and 2.8 m
Preglednica 1: Gostota rastlin in število navitih poganjkov v poskusu v hmeljiščih z medvrstno razdaljo 2,4 m in 2,8 m

Treatment	Distance between rows (m)	Distance between plants in a row (m)	Plant density (plants/ha)	No. of trained sprouts per string
1a	2.4 m	1.3	3200	3
2a	2.4 m	1.3	3200	4
3a	2.4 m	1.3	3200	5
4a	2.4 m	1.5	2800	3
5a	2.4 m	1.5	2800	4
6a	2.4 m	1.5	2800	5
1b	2.8 m	1.1	3200	3
2b	2.8 m	1.1	3200	4
3b	2.8 m	1.1	3200	5
4b	2.8 m	1.3	2800	3
5b	2.8 m	1.3	2800	4
6b	2.8 m	1.3	2800	5

The rest of the agrotechnique was the same for all plots and performed in the terms of good agricultural practise.

Both experiments were harvested plot by plot at the time of technological maturity (the first decade of September). For the evaluation the inner three rows were considered. Number of plants and strings per plot were counted, surface under harvested plots was measured. Yield per plots was weighted, samples for moisture and alpha acid content were taken and delivered to the laboratory of Slovenian Institute of Hop Research and Brewing.

2.3 Chemical analyses and data processing

Moisture content in hop cones was detected according to EBC Analytica (1998) [1], alpha acid content in cones according to EBC Analytica (2000) [2]. 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 Soil and weather conditions

Soil of the experimental field is sandy clay loam; pH value at the conduction of the experiment was 5.8, phosphorus supply excessive, potassium supply adequate (Table 2).

Table 2: Soil analyze results (AL method) at the conduction of the experiment
Preglednica 2: Analiza tal (metoda AL) pred postavitvijo poskusa

pH in KCl	P_2O_5 (mg/100 g soil)	K_2O (mg/100 g soil)
5.8	36.0	24.9

There were above average temperatures in the season of 2007. Extremely high temperatures were in the second half of July when maximum daily temperatures exceeded 35ºC. High temperatures oscillations were also observed; temperatures raised and decreased in a short time period even for 10°C. Average temperature from the beginning of April to the end of August was 18.2ºC; what is by almost 2 degrees higher compared to the long term average. April was warmer by 3.2ºC, May by 1.9ºC, the second decade of June by 4.4ºC and August by 0.3ºC compared to the long term average. 473 mm of precipitation were detected in the season of 2007; what is 116 mm less compared to the long term average. On the other hand precipitations were not equally disposed with regard to location, time and quantity.

In the growth season of 2008 (April to August) there was 713 mm precipitation, what is by 124 mm more compared to the long term average. Precipitation was locally and timely not uniform disposed; there were lots of showers and storms with hail which appear already in May. In the period from June to August there was 83% of all seasonal precipitation. There was only 47 mm precipitation in May and as much as 228 mm in June. Average temperature from the beginning of April to the end of August was 16.4°C, what is by more than 1°C higher compared to the long term average. April was warmer by 0.7°C and May by 1.6°C. Temperatures in June were very variable. The second decade was by 1.2°C colder compared to the long term average (minimum daily temperature was 9.9°C) but then, in the last decade of the month there were extremely high temperatures; in the majority of the days maximum daily temperature exceeded 30°C. Average temperature was higher by 4.6°C compared to the long term average. Warm weather, but not with temperatures over 30°C, continued in July and August.

In 2009 there were relatively high temperatures in May and then they decreased suddenly at the end of the month. That was expressed in non-uniform and long flowering and consecutive in non-uniform ripening. Different stages of ripeness were observed even on the same plant. Compared to the long term average, there was more precipitation in June 2009 (174 mm) and at the beginning of July. At the beginning of August there were relatively high temperatures.

3 RESULTS AND DISCUSSION

3.1 Second year of the experiment

There were no significant differences in the yield of cones per hectare, yield of cones per plant and alpha acids yield per hectare among treatments (1a to 6a, and 1b to 6b) in the second year of the experiment. At the same time there were significant differences in alpha acids content in hop cones of different treatments in the hop field with 2.4 m row distance, while not in the hop field with 2.8 m row distance (data not shown). In the hop field with 2.4 m row distance significantly the highest alpha acid content was reached with 2800 plants/ha and 5 trained sprouts per string (12.7% in DM). With regard to yield and alpha acids yield, it was indicated in both hop fields (row distances 2.4 m and 2.8 m) that in the second year of hop plantation higher plant density (3200 plants/ha) is favourable compared to lower plant density (2800 plants/ha).

3.2 A mature, productive hop garden

In the third year of hop plantation and later, it is considered as a mature, productive hop garden. In our experiment in the third and fourth season weather conditions had the highest impact on all examined parameters (yield of cones, alpha acids content, and alpha acids yield) (Table 3). In 2008 more favourable conditions for hops cv. Dana prevailed compared to 2009. With exception of the yield in hop field with 2.8 m row distance, all the other examined parameters were significantly higher in 2008 compared to 2009, namley.

Because plant density had no significant impact on all the examined parameters except yield per plant in the hop field with 2.4 m row distance (Table 3), lower plant density (2800 plants/ha) would be recommendable; it means lower expenses for plant material, strings, and less working hours for training, namely.

Table 3: Yield, alpha acids content and alpha acids yield in the hop fields with 2.4 m and 2.8 m row distances with regard to plant density (2800 plants/ha and 3200 plants/ha), number of training bines per string (3, 4, 5) and year (2008, 2009) in a mature plantation of hops cv. Dana

Preglednica 3: Pridelek, vsebnost alfa kislin in pridelek alfa kislin v hmeljiščih z medvrstnima razdaljama 2,4 m in 2,8 m glede na gostoto rastlin (2800 rastlin/ha and 3200 rastlin/ha), število navitih poganjkov (3, 4, 5) in leto raziskave (2008, 2009) v polnorodnem nasadu hmelja cv. Dana

	Yield (kg/ha DM)		Yield (kg/plant DM)		Alpha acid content (% in DM)		Alpha acid yield (kg/ha)	
Row distance:	2,4 m	2,8 m	2,4 m	2,8 m	2,4 m	2,8 m	2,4 m	2,8 m
Plant density 3.200	1487 *a**	1733 *b*	0,47 *a*	0,44 *a*	15,3 *a*	14,6 *a*	230 *a*	253 *a*
Plant density 2.800	1480 *a*	1599 *a*	0,53 *b*	0,49 *b*	14,9 *a*	14,8 *a*	225 *a*	236 *a*
Year 2008	1734 *b*	1660 *a*	0,58 *b*	0,56 *b*	16,2 *b*	15,8 *b*	281 *b*	263 *b*
Year 2009	1234 *a*	1672 *a*	0,42 *a*	0,37 *a*	14,0 *a*	13,6 *a*	173 *a*	227 *a*
3 trained bines	1457 *a*	1665 *a*	0,49 *a*	0,46 *a*	15,3 *a*	14,8 *a*	226 *a*	247 *a*
4 trained bines	1489 *a*	1648 *a*	0,50 *a*	0,46 *a*	15,0 *a*	14,8 *a*	227 *a*	244 *a*
5 trained bines	1505 *a*	1685 *a*	0,51 *a*	0,47 *a*	15,0 *a*	14,5 *a*	228 *a*	244 *a*

* The same letter in the column within one parameter (density, year, and number of traininig bines) indicates that there is no significant difference between treatments (Duncan multiple range test, $p<0.05$).

On the other hand, in the hop field with wider row distance (2.8 m), plant density had a significant impact on the yield per hectare and yield per plant. Significantly higher yield per plant was reached at lower plant density (2800 plants/ha) compared to 3200 plants/ha. But the difference in yield per plant was not that high to cover the lower number of plants at lower plant density, so at the end there was significantly higher yield per hectare at higher plant density (3200 plants/ha) compared to 2800 plants/ha (Table 3). So, with the goal of higher yield, higher plant density (3200 plants/ha compared to 2800 plants/ha) would be recommendable. But, actual hop prices are very low, thus the differences in yield between the

two investigated plant densities have to be compared with expenses in the hop fields, caused by higher number of plants (higher expenses for plant material and strings and more working hours for training).

With regard to results the number of trained bines per string did not have a significant impact on the examined parameters (Table 3), what should be the matter of further investigations.

4 ACKNOWLEDGEMENT

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