FERTIGATION EXPERIMENT ON SAAZ HOPS IN 2017-2019

Pavel DONNER[1] and Josef JEŽEK[2]

Professional article / strokovni članek
Arrived / prejeto: 25. 10. 2019
Accepted / sprejeto: 10. 12. 2019

Abstract
The three year (2017–2019) fertigation experiment with fine aroma hop variety Saaz was established in the Czech Republic in Saaz hop growing region. The control treatment included the contemporary growing technology without fertigation, just soil and foliar fertilization with 300 kg/ha of ammonium sulphate, 300 kg/ha of ammonium phosphate and 300 kg/ha of potassium chloride in the early spring, followed by 250 kg/ha of ammonium nitrate with limestone in May. Foliar fertilization mainly consisted of N, P, K, Zn and Mg application. The treatment with fertigation got basic dose of fertilizers (640 kg/ha of fertilizer containing NPK 20-7-10 + 4 % S, 2 % MgO) during sprouting, followed by fertigation 5-times (42,5 kg/ha of fertilizer containing NPK 12-12-36 + micro) and foliar application during vegetation period (various fertilizers containing mainly N, P, K, Zn, Mg, B, S). The amount of applied nitrogen, phosphorus and potassium was lower at the treatment with fertigation by 8,3 % N, 53,6 % P and 22,5 % K. The experiment proved the significant increase of yield by 27 %, 33 % and 16 % in 2017, 2018 and 2019 respectively at treatment with fertigation compared to control treatment and also the alpha-bitter acids content in hop cones was significantly higher in 2018 (by 14 %) at treatment with fertigation compared to control tretament. Nevertheless, in the years 2017 and 2019 there was no significant difference in alpha-bitter acids content between treatments. The results suggest that fertigation can intensify hop cultivation.
Key words: hop, irrigation, fertigation, water-soluble fertilizers

POSKUS FERIGACIJE HMELJA NA SORTI SAAZ V LETIH 2017 DO 2019

Izvleček
Triletni poskus (2017–2019) na področju fertigacije hmelja je bil postavljen v hmeljarski regiji Saaz na Češkem. Preučevana sorta je bila fina aromatična sorta hmelja Saaz. Kontrolno obravnavanje je vključevalo klasično pridelavo hmelja

[1] PhD student, Hop Research Institute Co., Ltd., Kadaňská 2525, 438 01 Žatec, Czech Republic, e-mail: donner@chizatec.cz
[2] PhD, Hop Research Institute Co., Ltd., Kadaňská 2525, 438 01 Žatec, Czech Republic, e-mail: jezek@chizatec.cz

brez fertigacije, samo gnojenje preko tal in foliarno gnojenje: 300 kg/ha amonsulfata, 300 kg/ha amonfosfata in 300 kg/ha kalijevega klorida zgodaj spomladi ter 250 kg/ha amonnitrata v maju. Foliarno gnojenje je vključevalo v glavnem hranila N, P, K, Zn in Mg. Obravnavanje s fertigacijo je vključevalo osnovni odmerek 640 kg/ha NPK 20-7-10 + 4 % S, 2 % MgO med vznikom, sledila je fertigacija 5-krat v sezoni (42,5 kg/ha NPK 12-12-36 + mikrohranila) in foliarno gnojenje z različnimi gnojili, ki so vsebovala v glavnem N, P, K, Zn, Mg, B in S. Količina apliciranih N, P in K je bila pri obravnavanju s fertigacijo manjša za 8,3 % N, 53,6 % P in 22,5 % K. Obravnavnje s fertigacijo je doseglo v letih 2017, 2018 in 2019 za 27 %, 33 % oziroma 16 % večji pridelek kot kontrolno obravnavanje. Vsebnost alfa-kislin v storžkih je bila pri obravnavanju s fertigacijo v letu 2018 značilno večja (za 14 %) kot pri kontrolnem obravnavanju, v letih 2017 in 2019 pa med obravnavanjema ni bilo značilne razlike v vsebnost alfa-kislin. Rezultati nakazujejo, da s fertigacijo lahko intenziviramo pridelavo hmelja.
Ključne besede: hmelj, namakanje, fertigacija, vodotopna gnojila

1 INTRODUCTION

Hop growing success depends, among other factors, on natural precipitation. The need of hops for additional water is crucial especially during hot and dry years. When using drip irrigation with drippers above the hop rows, the water is distributed directly to the hop roots. Under rainfed conditions, the soil directly below plants is usually not wet after light rain, because hop's biomass shades the row from the rain and most of the water stays on the leaves or flows down the leaves and lands around the plant, not directly under it. With drip irrigation the area below the hop plant, with a width of ca 1-1.2 m and with uneven rainwater distribution at ground level, becomes irrigated. Since hop is grown in different soils types, it is hard to state universal pattern of irrigation water distribution in the soil. The experiment was held on loamy fluvisol, where the irrigation water moving in the soil – both vertically and horizontally – forms an onion shape of damp soil around the plant root system. The sandier the soil is, the narrower (and more "carrot" shaped) the damp soil pattern is (Hillel, 1997; Goldy, 2015).

The usual way of mineral nutrition of Czech hops consists of application of industrial mineral fertilizers in autumn or early spring around the time of pruning. It is followed by application of nitrate in form of nitrogen-based mineral fertilizers right before first hill-building ploughing. There is optional third fertilization (usually nitrate nitrogen only) before second hilling, but it is based on leaf analysis and is not practiced every year. Foliar application of micronutrients (also based on leaf analysis) together with plant protection products also occurs during vegetation. This way of fertilization is used on farms without drip irrigation.

The aim of the experiment was to test the effect of water-soluble fertilizers on hop yield and alpha-bitter acids contents compared to control treatment practiced by hop growers without irrigation system.

2 MATERIAL AND METHODS

Experimental area was located in a hop garden of Hop Research Institute‘s Farm in Stekník (Saaz hop growing region) which is 8 km from the town Žatec (Saaz). Hop variety Saaz was used for this experiment. The hop rhizomes were planted in 2004. Distance between rows and plants was 3 m x 1 m, the hop bines were trained in V-shape. Theoretical number of plants reached 3333 plants per hectare. Soil type at the experimental hop garden was fluvisol on alluvial sediments located close to river Ohře (Eger), where average annual precipitation doesn’t exceed 500 mm and average annual temperature ranges between 8–9°C. Experiment was set up in a hop garden called „Zastávka V“ (0.52 ha). One treatment covered area of 0.11 ha – seven 55 m long rows. A unified cultivation technology, including plant protection, was held on the whole experiment the same. The whole experiment was irrigated (as required) by a drip irrigation placed on the wiring of hop garden (above the hop plants). Irrigation system consists of one dripline above a row with emitters 1m away from each other, each emitter discharges 2 l/h. Irrigation terms and dosages are shown in Table 1, weather conditions during vegetation periods are shown in Table 2. The hop gardens were irrigated as required, based on the decision of a skilled hop grower. The fertigation took 2 hours and was done at the end of (usually) 24 h long irrigation cycle (2 l/hour = 48 l/cycle).

There were two treatments: Control and Fertigation. The used fertilizers with regard to the treatment and contents of nutrients in fertilizers are summarized in Tables 3, 4 and 5. The control treatment, which is currently managed by a skilled hop grower, is presented in Table 3, the Fertigation treatment with water-soluble fertilizers is shown in Table 4. The sum of net content of selected macronutrients and zinc added in fertilizers are calculated in Table 5. Doses and terms of fertigation correspond with the demand on nutrients of hop plants concerning nitrogen, phosphorus, potassium, calcium, magnesium, sulphur and microelements such as zinc and boron. The basic dose of fertilizers was applied during sprouting, followed by fertigation 5-times and foliar application during vegetation period.

Table 1: *Irrigation terms and dosages in 2017–2019*

2017	
1. 6. 2017	22 l/plant (= 11 h x 2 l/h)
5. 6. 2017	48 l/plant (= 24 h x 2 l/h)
9. 6. 2017	28 l/plant (= 14 h x 2 l/h)
13. 6. 2017	86 l/plant (= 43 h x 2 l/h)
21. 6. 2017	48 l/plant (= 24 h x 2 l/h)
27. 6. 2017	48 l/plant (= 24 h x 2 l/h)
4. 7. 2017	48 l/plant (= 24 h x 2 l/h)
9. 7. 2017	48 l/plant (= 24 h x 2 l/h)
total 2017	376 l/plant
2018	
8. 6. 2018	48 l/plant (= 24 h x 2 l/h)
16. 6. 2018	48 l/plant (= 24 h x 2 l/h)
21. 6. 2018	48 l/plant (= 24 h x 2 l/h)
29. 6. 2018	48 l/plant (= 24 h x 2 l/h)
6. 7. 2018	48 l/plant (= 24 h x 2 l/h)
9. 7. 2018	48 l/plant (= 24 h x 2 l/h)
18. 7. 2018	48 l/plant (= 24 h x 2 l/h)
21. 7. 2018	48 l/plant (= 24 h x 2 l/h)
27. 7.2018	48 l/plant (= 24 h x 2 l/h)
12. 8. 2018	48 l/plant (= 24 h x 2 l/h)
total 2018	480 l/plant
2019	
08. 06. 2019	88 l/plant (44 h x 2 l/h
19. 06. 2019	36 l/plant (18 h x 2 l/h)
20. 06. 2019	40 l/plant (20 h x 2 l/h)
28. 06. 2019	48 l/plant (24 h x 2 l/h)
30. 06. 2019	40 l/plant (20 h x 2 l/h)
06. 07. 2019	48 l/plant (24 h x 2 l/h)
07. 07. 2019	40 l/plant (20 h x 2 l/h)
15. 07. 2019	40 l/plant (20 h x 2 l/h)
22. 07. 2019	40 l/plant (20 h x 2 l/h)
05. 08. 2019	40 l/plant (20 h x 2 l/h)
total 2019	460 l/plant

Table 2: *Weather conditions during 2017–2019 vegetation period*

	Temperatures (month avg.) [°C]				Precipitation (month sums) [mm]		
	2017	2018	2019		2017	2018	2019
April	8.9	13.7	10.6	April	47.2	15.6	28.4
May	15.6	17.7	12.4	May	21.4	41.8	60.4
June	19.8	19.3	22.8	June	48.6	48.2	19.8
July	20.4	22.1	20.9	July	67.2	17.0	31.0
August	20.1	22.4	20.4	August	65.8	10.2	47.2
Average	**17.0**	**19.0**	**17.4**	Sum	**250.2**	**132.8**	**186.8**

Table 3: *Control (hop growing in 2017–2019)*

BBCH	Month	Fertilizer	Dose	Application
01	March	ammonium sulphate (21% N; 13% S)	300 kg/ha	mounted spreader (m.s.)
		ammonium phosphate (12% N; 52% P_2O_5)	300 kg/ha	
		potassium chloride (60% K_2O)	300 kg/ha	
31-35	May	ammonium nitrate with limestone (27% N)	250 kg/ha	m. s.
34	May	zinc (700 g/l)	0.5 l/ha	spraying machine (sp.m.)
		magnesium sulphate (15% MgO)	5 kg/ha	sp. m.
36-38	June	zinc (700 g/l)	0.5 l/ha	sp. m.
		magnesium sulphate (15% MgO)	5.0 kg/ha	sp. m.
		leaf fertilizer 'A' (6% N; 5,7% P_2O_5; 6% K_2O)	10.0 l/ha	sp. m.
51& 55	July	leaf fertilizer 'A'	10.0 l/ha	sp. m.
63-67	July	leaf fertilizer 'A'	10.0 l/ha	sp. m.

In the middle of each August, we selected 32 random plants from both experimental and control plots. Those plants were selected only from inner rows. Number of bines on each wire was counted. All plants were harvested in the period of technological maturity. Hops harvested from each plant was weighed and recalculated on weight from one bine and weight of dry hops from 1 ha. The conversion ratio was set on the value of 4.1 (raw > dry hops). A sample of hops was taken from each harvested plant and analysed for alpha-acids content (ČSN 46 2520-15, Determination of alpha bitter acid by the conductometric method). The data were compared statistically using 'Microsoft Excel' software (Estimation and Testing > Two Sample Analysis).

Table 4: *Fertigation (hop growing in 2017–2019)*

BBCH	Month	Fertilizer (f.)	Dose	Application
09 & 11	April	'A' f. (20% N; 7% P_2O_5; 10% K_2O; 4% S; 2% MgO)	640 kg/ha	row spreading
35	June	'B' f. (12% N; 12% P_2O_5, 36% K_2O; + micro)	42.5 kg/ha	fertigation I (fert.)
35	June	'C' leaf f. (29,5% P_2O_5; 5% K_2O; 4,5% MgO; 3,1% Zn)	3.0 l/ha	spraying machine
		'D' leaf f. Boron (10,95% B; 150 g/l)	1.0 l/ha	sp. m.
36	June	'B' f.	42.5 kg/ha	fert. II
37	June	'E' leaf f. Zinc (40% Zn; 700 g/l)	0.5 l/ha	sp. m.
39	June	'C' leaf f.	3.0 l/ha	sp. m.
		'D' leaf f.	1.0 l/ha	sp. m.
39	June	'B' f.	42.5 kg/ha	fert. III
51 & 55	June	'B' f.	42.5 kg/ha	fert. IV
63	July	'B' f.	42.5 kg/ha	fert. V
65-69 & 71	July	'F' leaf f. (15,2% N; 22,8% S; 300 g S/l)	5.0 l/ha	sp. m.

Table 5: *Sum of net amount of selected macronutrients and zinc added in fertilizers*

[kg/ha]	N	P	K	Mg	S	Zn
Control	168	69	151	1.5	39	0.7
Fertigation	154	32	117	7.9	26	0.5

3 RESULTS AND DISCUSSION

The yields (averages of all 32 harvested plants) are shown in Table 6. The results of alpha-acid content (averages of 32 samples) are presented in Table 7. The significance difference between the treatments is shown in Tables 6 and 7.

The experiment with fertigation proved the increase of yield by 27 %, 33 % and 16 % in years 2017, 2018 and 2019 (Table 6). The aimed application of fertilizers (with mounted spreader and spraying machine) in connection with water-soluble fertilizers can assure an effective use of the nutrients. These results are closely related with the experiment in the USA (Delahunty and Johnston, 2015), where the increase of yield by fertigation, although it was done only in organic hop growing, was also confirmed. Hop growers in Hallertau (Germany) started to use fertigation in lower extent only few years ago after EU support on irrigation systems. The first results from Germany are summed up in master's thesis of Stampfl (2016), who published one-year results of experiment with fertigation from cultivars Perle and Herkules, stating, that statistical analysis didn't show expected results because of

weather conditions in 2016, when the effect of fertigation was limited due to sufficient amount of precipitation water and should be investigated more in the future.

Table 6: *Average yield of hop cultivar Saaz (dry hops after conversion; 32 plants evaluated)*

Year	Control	Experiment	Index	Statistics
	[t/ha]	[t/ha]	[%]	[significance]
2017	1.44	1.83	+27	Yes
2018	1.04	1.39	+33	Yes
2019	1.82	2.11	+16	Yes

Treatment did not have influence on alpha-acids content in hop cones in 2017 and 2019. The exception was the year 2018, when the significant increase of 14 %, compared to the Control, was recorded in Fertigation treatment. It seems to be caused by the unpredictable weather circumstances, where the negative effect on alpha-acids content is caused by high air temperatures (tropical days with over 30 °C) during second half of July and August (Türkott, 2005; Pokorný, 2011; Srečec et al., 2013). June, July and August in 2018 in the Czech Republic experienced several very hot periods. The fertigated plants seem to thrive better under hot weather conditions. The influence on alpha-acids' synthetic process is still hardly identifiable.

Table 7: *Average content of alpha acids in hop cones of cultivar Saaz (Determination of alpha bitter acid by the conductometric method, according to the Czech norm ČSN 46 2520-15)*

Year	Control	Experiment	Index	Statistics
	[% C-value]	[% C-value]	[%]	[significance]
2017	3.31	3.22	–3	No
2018	3.51	4.01	+14	Yes
2019	4.60	4.63	+1	No

4 CONCLUSIONS

Hop irrigation is an important stabilizing factor of profitable hop growing and enables the supply of nutrients in connection with water soluble (mineral) fertilizers (fertigation). In our experiment fertigation (5-times in the season) in combination of foliar fertilization (6-times in a season) significantly increased the hop yield in years 2017–2019 compared to the control treatment with no fertigation, just soil fertilization and foliar fertilization The amount of applied nitrogen, phosphorus and potassium was lower at the fertigation treatment by 8,3%

N, 53,6% P and 22,5% K compared to control treatment. The year 2018 proved the significant impact on the alpha-acids content in hop cones at the Fertigation treatment by 14% compared to control treatment, however, in 2017 and 2019 alpha-acids content remained unaffected by the treatment.

Acknowledgement. The work was supported by Czech Ministry of Agriculture within the Research Project No. MZE-RO1319.

5 REFERENCES

ČSN 46 2520-15 Determination of alpha bitter acid by the conductometric method. Czech Standardization Agency. Valid norm into force in December 1997

Delahunty, K., Johnston, J. Investigating best practices for timing and amount of organic soluble nitrate fertigation of hops in the Northeast. USDA Northeast SARE Final Report: FNE 14–796, 2015. Retreived from https://projects.sare.org/project-reports/fne14-796/ [cited 2019-10-23]

Goldy, R. Hop fertigation and nutrient management <online>. MSUE Southwest Michigan Research and Extension Center, 2015. Available at https://www.canr.msu.edu/uploads/236/71505/Hop_fertigation.pdf

Hillel, D. Small-scale irrigation for arid zones – principles and options. Food and agriculture organization of the United Nations, Rome, 1997, p. 21. ISSN 1020-0819

Meier, U. Growth stages of mono- and dicotyledonous plants: BBCH Monograph. Julius-Kühn Institut, Quedlinburg, 2018, 97-101, 184-185. DOI: 10.5073/20180906-074619

Pokorný, J. Influence of locality and year on hop production and quality. [in Czech] Ph.D. Thesis, 2011, Prague, Czech University of Life Sciences

Stampfl, J. Auswirkungen von Fertigation und Tropfschlauchpositionierung auf den Ertrag und die Inhaltsstoffe von Hopfen (*Humulus lupulus*) – Masterarbeit. Technische Unversität München, 2016. Available at https://www.lfl.bayern.de/mam/cms07/ipz/dateien/masterarbeitstampfl_feb2017.pdf

Srečec, S., Čeh, B., Savić Ciler, T., Ferlež Rus, A. Empiric mathematical model for predicting the content of alpha-acids in hop (*Humulus lupulus* L.) cv. Aurora. SpringerPlus, ISSN 2193-1801, 2013, vol. 2, 59, p. 1-5, DOI: 10.1186/2193-1801-2-59

Türkott, L. Vliv povětrnostních podmínek na růst a vývoj ozdravených a neozdravených klonů chmele [in Czech]. Bioklimatologie současnosti a budoucnosti, Křtiny 12. – 14.9.2005, ISBN 80-86 690–31-08