EFFECTS OF CONTROLLED REGIME ON HABITAT FORMATION OF HOP PLANT (*HUMULUS LUPULUS* L.) DURING VEGETATION

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Irrigation of hop plants in the period of moisture deficiency is increasing an amount of produced dry matter in conversion per hop plant statistically significantly. In 1997 more dry matter by 31.58% was produced in irrigated plants and in 1998 by 22.37% more dry matter than in non-irrigated ones. Significant differences between non-irrigated and irrigated plants were recorded in dry matter of hop cones. In 1997 more dry matter of hop cones by 32.37% was in irrigated variant compared with non-irrigated variant, and in 1998 it was more by 28.75%. Irrigation also increases assimilation leaf area of a hop plant statistically significantly. In 1997 maximum leaf area found on 13 August was 4.736 m^2 in irrigated variant and 3.455 m^2 in non-irrigated variant. In 1998 maximum leaf area was 3.160 m^2 in irrigated variant with respect to more frequent start of vegetation already on 15 July. Maximum leaf area was 2.946 m^2 in non-irrigated variant on 17 August.

hop; irrigation; dry matter; leaf area

INTRODUCTION

Hop is a plant much demanding for amount of precipitation and predomi-antly on their suitable distribution during vegetation. Different authors re-ort different amount of water needed for hop growth and development. As eported M o h l (1924), the annual sum of precipitation ranging from 450 600 mm is needed. L i n k e and R e b e l (1950) consider 300 l water onsumption per each kilogram of hop organic matter. V e n t (1963) reports at 500 l of water is needed to produce 1 kg of green matter. Z á z v o r k a nd Z i m a (1956) calculated the need of precipitation according to the oduction of dry matter per 1 hectare and came to the amount of precipita-on 235 mm. However, optimal ratio of precipitation and temperatures is prerequisite of the yield.

There are different opinions among the different authors on the period, where the hop is the most demanding for plenitude of precipitation.

A correct distribution of precipitation in the months May, June and July is a prerequisite of good yield as considered by Linke (1942) and Zázvorka, Zima (1956). On the contrary, according to Osvald (cit. Vent, 1963), May precipitation is less important than precipitation in June and July. This has been also confirmed by Klapal and Klapal (1963), but only under presupposition that April was rich in precipitation.

Slavík (1971) states that the hop has the maximum demands for precipitation in the time of the most intensive growth, i.e. in June. Almost two thirds of the total biomass of plant and shoots grow in this month. Lower amount of precipitation is more suitable in August, i.e. to the end of vegetation, as their high amount has adverse effects on the quality of cones.

Hautke and Petříček (1972) report that the yield level is much affected by precipitation in the last third of July and first half of August. Pastyřík (1973) is also of the similar opinion, and he gives, that the hop yield is very influenced by precipitation in July and August.

Based on the knowing of the demands of hop for amount of precipitation and their distribution during vegetation, problems of the utilisation of irrigation to increase the hop yields was studied in detail.

Sachl and Kopecký (1972) in field trials proved 25.9% increase of the yield by application of single irrigation rates amounting to 30 mm at the onset of anthesis and in the period of cone formation. Along with it, a good effect of irrigation on the hop quality and the content of brewer's most important components were found.

Ristic (1986) was dealing with the hop yield with irrigation and without it. He found that when the hop was cultivated in conditions with irrigation, the yield increased from 8.51 to 22.13% compared with the hop cultivated without irrigation.

Kopecký (1991) studied the effect of trickle irrigation on the quality and yield of hop cones. He reports that replicated trickle irrigation in a suitable date has a positive effect on the yield and quality of cones. Yield increase for the studied period was 26% on average, compared with the control.

Sasin (1993) compared the methods of control of irrigation regime utilizing meteorological data and physiological parameters. Statistically significantly highest yield was achieved at the control of irrigation by the method of measurement of osmotic potential. In addition he presents that irrigation applied it time in the second half of June will cause that plants will grow up to the height of frame and thus the formation of conic habitat will be eliminated. Together with it will be improved branching of shoots. Irrigation applied before anthesis and in the time of anthesis will improve the setting

of flowers and will provide balance of hop cones in the period before cone formation.

Slavík and Kopecký (1994) have proved production and economic efficiency of trickle irrigation. They present that the yield of 13.16 $t.ha^{-1}$ was accomplished by five irrigation rates, what represents an effectiveness of irrigation 3.56 $t.ha^{-1}$. The quality in the given trials was not affected by irrigation significantly.

Decrease of the yield by 0.22 $t.ha^{-1}$, i.e. by 22% (Slavík, Kopecký, 1997), occurred when moisture deficits were acted.

MATERIAL AND METHODS

Plants of Saaz semi-early red-bine hop, Osvald's clone 72, were the experimental plant material. Field trials were established in two variants: non-irrigated and irrigated ones. Irrigation was provided through trickle irrigation distributed above the rows of hop controlled in weekly balance cycles. During vegetation traditional agrotechnics was used in both variants. The sampling date of experimental plants was determined to catch the main stages in the growth of hop plant. The first sampling of plants was in the period after establishment of hop bines on hop training to the height of stand 2 m (May), the second sampling was at the height 2 to 4 m (June), the third sampling was at the height of stand 4 m to the top of hop garden frame (July), the last sampling was before ripeness of cones (August).

Aboveground part of four selected average hop plants was taken during each sampling. As the hop stem grows to the height of 9 m, aboveground part of these plants for further processing was divided into three storeys. Each storey of hop plant was analysed by organ structure into leaves on bines, leaves on shoots, bine and bine of shoots, including leaf stalks and generative organs – flower, flower cover and cones. Weight of dry matter of different organs and the whole hop plant was determined from the samples of plant material.

Along with it, leaf area of leaves on bines and on shoots on a hop plant were measured. The method of determination of leaf area was based on the principle of determination of assimilation area of average sample of leaves of known weight of dry matter and conversion into the total sample of leaves.

The results obtained were statistically evaluated by analysis of variance.

Tables I and II present weather characteristics of experimental years and irrigation rate.

I. Average daily temperature and sum of precipitation (Žatec 1997, 1998)

Month	Average daily temperature (°C)			Sum of precipitation (mm)		
	normal (°C)	1997	1998	normal (mm)	1997	1998
April	7.8	6.2	10.4	29.0	22.8	14.6
May	12.6	14.5	15.1	59.0	26.8	7.4
June	16.0	16.4	18.7	56.0	44.6	75.0
July	17.5	17.8	18.3	71.0	77.2	59.0
August	16.7	18.9	18.1	55.0	39.4	32.0

II. Survey of irrigation rates in irrigated variant

Date	Amount (mm^3)		Amount of water per efficiently irrigated area (mm)	
	1997	1998	1997	1998
May	15	52	9.25	32.09
June	27	23	16.65	14.21
July	20	29	12.35	17.97
August	9	25	5.55	14.81
In total	71	129	43.80	79.08

RESULTS AND DISCUSSION

Dry matter of hop plant was increasing gradually during the vegetation in both experimental years in both variants of the trial. The greatest amount of dry matter was obtained in the last date of measurement, i.e. before the harvest. At the beginning of the vegetation values of the amount of dry matter were ranging from 34.07 to 46.43 g and in the period before the harvest from 437.89 to 779.36 g (Table III).

P i c h l and R y b á č e k (1974) state that the amount of dry matter during vegetation is gradually increasing during vegetation. To the date 19 May they report the weight of dry matter 8.39 g and to the date 24 August 310.17 g.

R y b á č e k (1975), too, presents that dry matter of the system of above-ground organs was continuously growing to 4 September. Some changes in the rate of its growing are connected with the start of main phenological stages.

Along with it, R y b á č e k et al. (1981) give in their trials that the greatest amount of dry matter was gained at the end of August during the harvest and technical ripeness of cones.

III. The total amount of dry matter produced in different organs in conversion per hop plant

Variant	Dry matter in g	1997				1998			
		date of sampling				date of sampling			
		26.5.	16.6.	14.7.	13.8.	18.5.	9.6.	15.7.	17.8.
Non-irrigated	leaves on bines	17.22	79.01	109.66	148.76	24.37	69.22	97.54	95.86
	leaves on shoots	–	11.78	61.00	93.76	–	4.63	49.20	71.83
	bine	16.85	77.46	200.08	118.92	15.95	42.07	118.08	190.76
	cones	–	–	19.66	172.21	–	0.15	7.45	79.44
	in total	34.07	168.25	390.40	533.65	40.32	116.07	272.27	437.89
Irrigated	leaves on bines	22.01	78.11	141.42	146.72	27.30	82.52	126.37	103.70
	leaves on shoots	–	15.14	105.68	150.07	–	11.48	80.29	105.85
	bine	21.60	86.43	305.84	227.93	19.13	53.62	136.55	243.05
	cones	–	–	28.13	254.64	–	0.9	15.69	111.50
	in total	43.61	179.68	581.07	779.36	46.43	148.52	358.90	564.10

IV. Statistical evaluation of amount of dry matter in experimental variant

Variant of the trial	Number	Average	Homogenous groups
Non-irrigated	4	249.12	*
Irrigated	4	337.71	*

It follows from the results obtained, that irrigation of hop in the period of deficiency of precipitation increases an amount of dry matter in hop plants statistically significantly (Table IV). In 1997 the amount of dry matter increased by 31.58%. In 1998, when precipitation deficiency was more marked than in 1997, more dry matter only by 22.37% was produced in irrigated plants compared with non-irrigated ones.

In precipitation-deficiency year of 1998 less dry matter by 17.94% was produced in non-irrigated variant and in irrigated variant it was less by 27.62% dry matter than in 1997. It follows from it, that in the years with more significant precipitation deficiency, the difference in the amount of produced dry matter between irrigated and non-irrigated plants is falling.

We recorded the changes in the share of different organs on the amount of dry matter of the whole plant during vegetation. R y b á č e k et al. (1979) came to the same conclusion.

Dry matter of leaves on bines predominantly reached the highest values in hop plant to the mid-June. In the half of July dry matter of hop bines prevailed, that fell before the harvest of hop. In the period before harvest dry matter of hop cones reached maximums in both variants in 1997.

In the experimental year 1998 there was other share of different organs in the total dry matter before the harvest of hops. Dry matter of hop cones did not reach maximum in that period, but dry matter of hop bines was dominant. In the latter the weight of dry matter did not fall as it was in the previous year. These differences are apparently caused by the fact that in 1998 hop bines were still growing, but in 1997 in the period of ripening of cones the hop bine was not increasing.

The difference in the production of dry matter of particular organs between non-irrigated and irrigated variant was recorded also in leaves on shoots and on bines prior to harvest. In irrigated variant in this period dry matter of leaves on shoots was prevalent in contrast to non-irrigated variant, where dry matter of leaves on bines prevailed. It follows from this result that irrigation had a good effect on formation of leaves on shoots. On the contrary, deficiency of water reduces it.

In connection with dry matter of leaves, Rybáček et al. (1979) present that at the beginning of vegetation – the beginning of June, assimilation capacity is determined by leaves on bines, while at the end of vegetation, when these leaves are turning yellow and dying away, they are falling down.

Pronounced differences between non-irrigated and irrigated plants were recorded in the dry matter of hop cones. In 1997 in irrigated variant more dry matter of hop cones was produced by 32.37% compared with non-irrigated one, and in 1998 by 28.75%.

This result can be compared with the data of other authors studying the yield increase in irrigated plants against non-irrigated ones.

Sachl and Kopecký (1972) confirmed 25.9% yield increase in irrigated plants in their trials. Němec (1984) reports that yield increase by 21% was in irrigated variant.

Ristic (1986) presents yield increase by 8.51 to 22.13% in hops cultivated with irrigation. Kopecký (1991) reports that in irrigated plants on average yield increase amounted to 26% compared with the control over the period under study.

Slavík and Kopecký (1997) found that 22% yield increase was recorded in irrigated plants.

Higher precipitation deficiency in 1998 affected significantly the dry matter of hop cones. In non-irrigated variant it was less dry matter by 53.87% than in 1997 and in irrigated variant in 1998 less dry matter by 56.21% was produced compared with 1997.

Of the total dry matter 32.27 to 32.67% fell on hop cones in 1997 and in 1998 it was only 18.15 to 19.77%.

Hop plant has owing to great leaf area given prerequisites for intensive photosynthetic assimilation, while, as reported by Kišgeci (1974), the number of leaves per plant, and particularly the number of leaves on shoots is affected by weather conditions. When compared the growth of leaf area in both experimental years, it can be said, that differences between both the years are statistically insignificant, because more marked deficiency of precipitation in 1998 was recorded.

It follows from the results obtained, that in both experimental years during the whole vegetation greater leaf area was produced in irrigated plants than in non-irrigated ones. This difference is statistically significant (Table V). In 1997 maximum leaf area was on 13 August (in irrigated variant 4.736 m^2 and in non-irrigated variant 3.455 m^2). In 1998 maximum leaf area 3.160 m^2 was in irrigated variant with respect to earlier start of vegetation yet on 15 July. In non-irrigated variant maximum leaf area 2.946 m^2 was on 17 August (Table VI).

Zázvorka and Zima (1956) give the highest values of the leaf area index before harvest 4.630 m^2 and Cígler (1980) came to similar results. On the contrary, Skládal et al. (1973) stated that the greatest leaf area was in the last week of July. According to Rybáček et al. (1976) there are two peaks of the size of leaf area. One is in the last week of July and the second one in the first week of September due to continuing increments of leaves on shoots. Rybáček and Hradecká (1985) present in other trials the date of achieving the greatest leaf is in the period from 13 to 27 August.

Dynamics in the growth of leaf area is different in different types of leaves. It follows from the results that to the mid-July leaf area of leaves on bines prevails and in the period before the harvest leaf area of leaves on shoots is prevalent. These results roughly correspond to the observation of Kišgeci (1974) and Rybáček et al. (1976), who report that in leaves on bines area increases to the period of anthesis, while leaves on shoots increase leaf area even in the period of the growth of cones.

The exception was the year 1997, when leaf area of leaves on bines prevailed during the whole vegetation period in non-irrigated variant. On the contrary, in irrigated variant leaves on shoots had assimilation area 2.500 m^2 in this year and leaves on bines it had 2.236 m^2. In 1998 in the period before harvest assimilation leaf area of leaves on bines was dominant in both variants (non-irrigated variant: leaves on shoots 1.534 m^2, leaves on bines 1.412 m^2; irrigated variant: leaves on shoots 1.791 m^2 and leaves on bines 1.369 m^2). These values can be compared with the results of Kišgeci (1974), who

V. Statistical evaluation of the size of leaf area in experimental variants and experimental years

Variant of the trial and experimental year	Number	Average	Homogenous groups
Non-irrigated	4	0.92	*
Irrigated	4	1.23	*
1997	4	0.96	*
1998	4	1.19	*

VI. The development of leaf area in leaves on bines and leaves on shoots in conversion per hop plant

Variant	Leaf area in m^2	1997				1998			
		date of sampling				date of sampling			
		26.5.	16.6.	14.7.	13.8.	18.5.	9.6.	15.7.	17.8.
Non-irrigated	leaves on bines	0.308	1.325	1.482	1.957	0.430	1.156	1.183	1.412
	leaves on shoots	–	0.310	1.300	1.498	–	0.078	0.883	1.534
	in total	0.308	1.635	2.782	3.455	0.430	1.234	2.066	2.946
Irrigated	leaves on bines	0.423	1.431	2.023	2.236	0.482	1.195	1.718	1.369
	leaves on shoots	–	0.409	1.961	2.500	–	0.497	1.576	1.791
	in total	0.423	1.840	3.984	4.736	0.482	1.692	3.294	3.160

reports that in leaves on bines leaf area is ranging from 1.035 to 2.804 m^2 and in leaves on shoots from 2.586 to 8.331 m^2.

It is evident from the results that in irrigated variant leaves on shoots prevailed over leaves on bines more markedly compared with the non-irrigated variant. This corresponds to the observation of Kišgeci (1974), who presents that irrigation had good effects on the number of leaves on shoots (Tables VII and VIII).

As far as the vertical structure of leaf area is concerned, it can be said that the greatest leaf area of leaves on bines and leaves on shoots was in both variants in the first and second storeys of a hop plant. Differences in the size of leaf area between these storeys are statistically insignificant. In the third storey of hop plant leaf area was in both variants statistically significantly lower (Table V).

Cígler (1980) came to different results and reports that in the time of harvest leaves on bines had the greatest leaf area in the second storey of hop plant, leaves on shoots had this maximum in the third storey. Kafka (1972),

VII. The development of leaf area in different storeys in conversion per hop plant

Variant	Leaf area in m^2	1997				1998			
		date of sampling				date of sampling			
		26.5.	16.6.	14.7.	13.8.	18.5.	9.6.	15.7.	17.8.
Non-irrigated	1st storey	0.173	0.667	1.203	1.565	0.192	0.577	0.626	1.231
	2nd storey	0.102	0.763	1.077	1.417	0.189	0.490	1.027	1.381
	3rd storey	0.033	0.205	0.504	0.475	0.049	0.167	0.413	0.334
Irrigated	1st storey	0.174	0.864	1.804	2.115	0.215	0.677	1.180	1.484
	2nd storey	0.200	0.799	1.664	1.726	0.216	0.715	1.497	1.287
	3rd storey	0.050	0.177	0.520	0.896	0.051	0.300	0.617	0.389

VIII. Statistical evaluation of leaf area size between different storeys of hop plant

Storey	Number	Average	Homogenous groups
1st storey	4	0.32	*
2nd storey	4	0.91	*
3rd storey	4	0.92	*

too, reports that the size of leaf area of leaves on bines increases during the growth from lower leaves to those placed in the third fourth part of a hop plant.

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Vliv řízeného závlahového režimu na utváření habitu chmelové rostliny v průběhu vegetace.

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Chmel je rostlina značně náročná na množství srážek a především na jejich vhodné rozložení během vegetace. Zavlažování chmelových rostlin významně ovlivňuje utváření habitu chmelové rostliny a v konečném důsledku výnos chmelových hlávek. V našich pokusech jsme proto sledovali tvorbu sušiny a vývoj listové plochy u zavlažovaných a nezavlažovaných rostlin chmele. Uváděné hodnoty jsou přepočteny na jednu rostlinu chmele. Z dosažených výsledků vyplývá, že zavlažování chmele v období deficitu srážek statisticky významně zvyšuje množství sušiny u chmelových rostlin (tab. IV). V roce 1997 toto zvýšení činilo 31,58 %. V roce 1998, kdy byl výraznější srážkový deficit než v roce 1997, bylo u zavlažovaných rostlin vytvořeno pouze o 22,37 % více sušiny než u nezavlažované varianty. Významné rozdíly mezi nezavlažovanými a zavlažovanými rostlinami byly v obou pokusných letech v sušině chmelových hlávek. V roce 1997 bylo u zavlažované varianty oproti nezavlažované variantě zjištěno o 32,37 % a v roce 1998 o 28,75 % více sušiny chmelových hlávek (tab. III).

Chmelová rostlina má díky vysoké listové ploše dány předpoklady k intenzivnímu průběhu fotosyntetické asimilace. Přičemž, jak uvádí Kišgeci (1974), je počet listů na rostlině a zejména počet pazochových listů ovlivněn klimatickými podmínkami. Z dosažených výsledků vyplývá, že v obou pokusných letech byla v průběhu celé vegetace u zavlažovaných rostlin vytvořena větší listová plocha než u nezavlažovaných rostlin. Tento rozdíl je statisticky průkazný (tab. V). V roce 1997 byla maximální listová plocha zjištěna 13. srpna (u zavlažované varianty 4,736 m^2 a u nezavlažované varianty 3,455 m^2). V roce 1998 byla maximální listová plocha 3,160 m^2 u zavlažované varianty vzhledem k časnějšímu nástupu vegetace zaznamenána již 15. července. U nezavlažované varianty byla maximální listová plocha 2,946 m^2 zjištěna 17. srpna (tab. VI). Z hlediska vertikální struktury listové plochy lze konstatovat, že u obou variant byla největší listová plocha révových a pazochových listů v prvním a ve druhém patře chmelové rostliny (tab. VII a VIII).

chmel; závlaha; sušina; listová plocha

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