CHANGES IN ENERGY CONTENT IN VEGETATIVE AND GENERATIVE HOP ORGANS (*HUMULUS LUPULUS* L.) DURING VEGETATION

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The content of net energy in the conversion to the whole hop plant and different organs is significantly affected by irrigation. Differences between irrigated and non-irrigated plants in the amount of accumulated energy between irrigated and non-irrigated plants are in July, i.e. in the formation of hop cones. Significant differences are also in the amount of accumulated energy in hop cones when in irrigated plants more net energy by 23.33 to 30.46% was measured than in non-irrigated ones.

hop; irrigation; accumulation of net energy

INTRODUCTION

The study of energy accumulation in plant tissue allows to evaluate efficiency of energy conversion in photosynthesis on the basis of increments of internal energy in tissue (Šesták, Čatský, 1966). With respect to different values of energy of containing substances and their different representation in plants but also in their different organs, energy is not accumulated evenly by plant species or their organs. It follows from it that the energy content has a dynamic character in plants during the vegetation (Golley, 1961; Lieth, 1977). The growth of energy is therefore bound to the content of substances produced by photosynthesis and their further metabolic transformations. Except the effect of intensity of photosynthesis, the effect of genotype and action of external environment participates in energy value of biomass, as reported by Golley (1961).

The hop growth, and hence biomass production and energy accumulation, as much affected by sum of precipitation and their correct distribution during vegetation. Therefore, in our trials we were dealing with the effect of irrigation on accumulation of net energy into vegetative and generative organs of hops during vegetation. Amount of accumulated net energy is correlated with amount of produced dry matter both in the whole hop plant and in different organs. Despite it the study of net energy gives more exact picture on the production, consumption and transport of assimilates produced by photosynthesis.

MATERIAL AND METHODS

The experimental plant material were plants of Saaz semi-early red-bine hop, clone 72. Field trials were established in two variants: irrigated and non-irrigated ones. Irrigation was provided through trickle irrigation distributed above the rows of hops. Irrigation regime was controlled by prognosis of consumption of efficient irrigation rates in weekly balance cycle (Table I). During vegetation traditional cultural practices were used in both variants. The sampling date of experimental plants was determined to the main phases in the growth of a 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 done at the height of stand 2 to 4 m (June), the third sampling was at the height of stand 4 m to the top of hop frame (July), the last sampling was before ripeness of cones (August).

For each sampling above-ground part of four average hop plants was taken from 40 plants in the stand. As the top stem grows to 9 m, above-ground part of these plants was divided into three storeys. Each storey of hop plant was analysed according to the organ structure into leaves on bines, leaves on shoots, bines and small bines of shoots, including leaf stalks and generative organs: flower, cover and cones.

After drying in the drying room to the constant weight, weight of dry matter of organs of hop plants in different storeys was determined. Average 1 g samples were prepared from dry matter to determine burning heat. To measure burning heat, adiabatic burning calorimeter LAGET MS 10A was used. Burning heat was calculated using the Czechoslovak Standard ČSN 44 1352 (without correction to solving heat of sulphuric acid and nitric acid).

Burning of each sample was replicated three times. The total content of net energy (energy without ashes) in KJ in dry matter of different organs of hop plant was determined from the values obtained.

I. Survey of supplied amount of irrigation water

Date	Amount in $m^3.ha^{-1}$		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
Total	71	129	43.80	79.08

RESULTS AND DISCUSSION

Weather conditions of both experimental years were not favourable for the growth and development of hops. Both the years were above average regarding temperature, but below the average for precipitation. In 1997 the sum of precipitation for the period April to August was 210.8 mm, what is less by 59.2 mm than the normal (long-time average). In 1998 in the same period the sum of precipitation was 188.0 mm, what is less by 82.0 mm than the normal (Table II). Precipitation deficit which arose was controlled by irrigation. In 1997 in experimental area 43.8 mm of precipitation was substituted by irrigation and in 1998 79.08 mm of precipitation (Table I).

Such unfavourable years for the growth of hop reflected both in the yield formation and in the total accumulation of net and in different organs, as well as in the whole plant, of course.

During the vegetation the content of energy in the above-ground part of hop plant was increasing gradually in the whole above-ground part of hop plant in both variants and experimental years, what is given by increasing amount of biomass.

When evaluating the effect of the year as affected accumulation of energy in the above-ground part of plant, there was no statistically significant difference between experimental years. This was evidently caused by the fact that in 1998 when more energy was accumulated per unit of dry matter when less biomass was produced.

II. Survey of average temperatures and precipitation in different decades from April to August 1997 and 1998 – Žatec

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

In both experimental years more energy was in irrigated plants during the whole vegetation compared with non-irrigated ones. Greatest differences in the content of net energy between non-irrigated and irrigated variants were recorded in mid-July, i.e. in the period of formation of hop cones. In 1997 in this period in one irrigated plant was accumulated 7 460.43 KJ on average, what is more energy by 30.54% than in non-irrigated plants (5 181.70 KJ). In 1998 5 724.36 KJ were accumulated in irrigated plants in the same period, i.e. more by 29.00% than in non-irrigated plants (4 064.28 KJ). In the period before the harvest of hop bines was in one hop plant concentrated from 6 675.2 KJ to 9 702.9 KJ (Table III). It follows from these results that irrigation of hop plants increases significantly the total amount of net energy in above-ground part of hop plant.

This result corresponds to the conclusions made by Čislák, Heldi (1984) who report an example of the following crops: winter wheat, maize, sugar beet and annual fodder crops that total production of energy was always higher in irrigated plants.

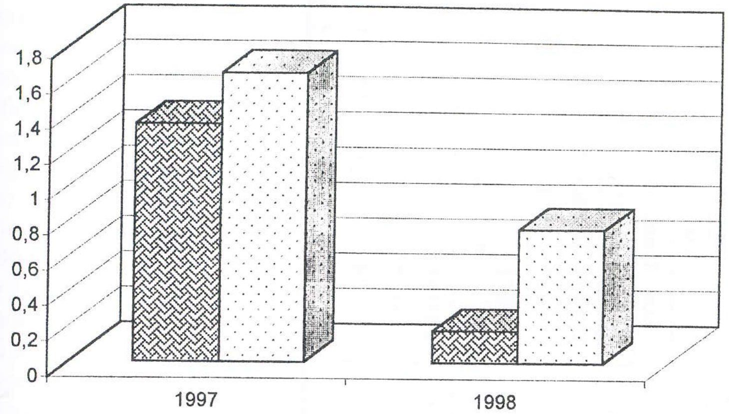
Differences in accumulation of net energy can be also found on the level of different organs of a hop plant (Table IV).

In hop cones is a marked difference in the content of energy not only between variants but also between experimental years. In 1997 in non-irrigated variant was 2 320.32 KJ of energy and in irrigated variant it was 3 336.75 KJ, i. e. 30.46% growth. In 1998 1 081.19 KJ in non-irrigated and 1 410.19 KJ in irrigated variant, i.e. 23.33% increase. Decrease in the content of energy in hop cones in was 46.60% in non-irrigated variant and 42.26 % in irrigated variant. These marked differences between experimental years were caused by the fact that in 1998 due to the deficit of moisture less hop cones were produced compared with 1997.

These results correspond with the yields of hop cones. In 1997 the yield of dry hop cones 1.64 $t.ha^{-1}$ was recorded in irrigated plants and 1.35 $t.ha^{-1}$ in non-irrigated ones. In 1998 a marked precipitation deficit was manifested

III. Total net energy in above-ground part of a hop plant

	Total net energy in KJ							
	1997				1998			
	date of sampling				date of sampling			
Variant	26.5.	16.6.	14.7.	13.8.	18.5.	9.6.	15.7.	17.8.
Non-irrigated	561.88	2 784.73	5 181.7	7 951.41	615.28	1 969.72	4 064.28	6 675.22
Irrigated	730.05	2 990.54	7 460.43	9 702.94	726.64	2 427.34	5 724.36	8 369.99



1. Yield of dry hop cones (1997 and 1998)

x-axis – year of experiment, y-axis – yield of dry hop cones ($t.ha^{-1}$)
▨ non-irrigated variant, □ irrigated variant

also in irrigated plants in which the yield of dry hop cones amounted to 0.76 $t.ha^{-1}$ and 0.18 $t.ha^{-1}$ only (Fig. 1) in non-irrigated plants.

Energy accumulated in hop cones in 1997 represents 29.18% in non-irrigated variant and 34.40% in irrigated variant of the total amount of net energy. In 1998 in hop cones of the total amount of energy in non-irrigated variant was only 16.20% and 16.85% in irrigated variant. These data can be compared with the results obtained by Kafka (1983) who gives that 25 to 35% of energy is accumulated in hop cones of the total amount of energy.

The effect of the year was not significantly reflected in accumulation of energy in leaves on shoots. Certain differences were recorded in the content of energy in these leaves between variants when in mid-July much more energy was accumulated in leaves on shoots in irrigated variant than in non-irrigated variant.

Differences in accumulation of energy between the years were reported also in hop bines. In 1997 much more energy was accumulated in hop bines in the period from 16 June to 14 July compared with the fact that in 1997 were more favourable conditions for their intensive growth. In addition, in 1997 in the period before the harvest the content of energy in hop bines decreased. In 1998, on the contrary, the content of energy in hop bine rose in the period before harvest. Simultaneously with it, there were differences between variants in accumulation of energy into bine. More energy was

IV. Total net energy in different organs

Variant	Organ of hop plant	Total net energy in KJ							
		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	RL	289.08	1 384.79	1 641.53	1 994.2	383.64	1 213.39	1 589.51	1 489.76
	PL	-	184.43	898.08	1 148.25	-	76.62	821.24	1 142.90
	R	272.80	1 215.51	2 377.31	2 488.64	231.64	679.71	1 520.95	2 961.37
	HL	-	-	264.78	2 320.32	-	-	132.58	1 081.19
Irrigated	RL	375.20	1 342.22	1 755.05	1 786.63	450.91	1 334.88	2 252.04	1 560.22
	PL	-	229.06	1 605.46	1 749.78	-	244.92	1 357.74	1 748.37
	R	354.85	1 419.26	3 708.46	2 829.78	275.73	847.54	1 863.69	3 651.21
	HL	-	-	391.46	3 336.75	-	-	250.89	1 410.19

RL – leaves on bines, PL – leaves on shoots, R – bine, HL – cones

accumulated in hop bine in irrigated variant compared with non-irrigated variant one.

The only organ where differences between variants were not significantly manifested were bine leaves.

Based on the knowledge of the content of energy in one average time of a hop plant (including cones) the total amount of energy produced per hectare can be estimated. In 1997 in the period before the harvest 53.00 $GJ.ha^{-1}$ were accumulated in non-irrigated variant and 64.68 $GJ.ha^{-1}$ in irrigated variant. In 1998 44.50 $GJ.ha^{-1}$ were accumulated in non-irrigated variant and 55.79 $GJ.ha^{-1}$ in irrigated variant. The total amount of energy comprised in hop mash per hectare was studied by Kafka (1983) who reports that 59 to 97 $GJ.ha^{-1}$ of energy remain non-utilised after the harvest.

Increased amount of energy in irrigated variant compared with non-irrigated variant in 1997 amounted to 11.68 $GJ.ha^{-1}$ and 11.29 $GJ.ha^{-1}$ in 1998. Increased energy after irrigation in some crops was reported by Strašil (1987). It follows from the results that irrigation in both experimental years markedly increased not only the amount of energy accumulated by plants, but silmultaneously with it also the amount of energy accumulated per hectare of hop garden.

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HNILIČKOVÁ, H. – NOVÁK, V. (Česká zemědělská univerzita, Agronomická fakulta, Praha, Česká republika):

Změny obsahu energie ve vegetativních a generativních orgánech chmele (*Humulus lupulus* L.) během vegetace.

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Akumulace energie má během vegetace dynamický charakter a je ovlivňována genotypem a průběhem povětrnostních podmínek (Golley, 1961; Lieth, 1977). Chmel je rostlina velmi náročná na množství a správné rozložení srážek během vegetace. Nedostatek srážek lze řešit zavlažováním, na které chmel citlivě reaguje. Proto jsme se v letech 1997 a 1998 zabývali fotosyntetickou akumulací energie do jednotlivých nadzemních orgánů u zavlažovaných a nezavlažovaných chmelových rostlin (Osvaldův klon 72).

Na základě výsledků lze konstatovat, že zavlažování významně zvyšuje množství akumulované netto energie v chmelové rostlině. Největší rozdíly v obsahu netto energie mezi nezavlažovanou a zavlažovanou variantou byly v polovině července, tedy v období tvorby chmelových hlávek. V roce 1997 bylo v tomto období u zavlažovaných rostlin v průměru o 30,54 % více energie než u nezavlažovaných rostlin, v roce 1998 pak o 29,00 % více (tab. III). Významné rozdíly jsou rovněž v množství energie akumulované v chmelových hlávkách, kdy u zavlažovaných rostlin bylo naměřeno o 23,33 až 30,46 % více netto energie než u nezavlažovaných rostlin. Tyto výsledky jsou v souladu s výnosem chmelových hlávek. V roce 1997 byl u zavlažovaných rostlin výnos suchých chmelových hlávek 1,64 $t.ha^{-1}$ a u nezavlažovaných rostlin 1,35 $t.ha^{-1}$. V roce 1998 se výrazný srážkový deficit projevil i u zavlažovaných rostlin, u kterých byl výnos suchých chmelových hlávek 0,76 $t.ha^{-1}$, zatímco u nezavlažovaných rostlin byl pouze 0,18 $t.ha^{-1}$ (obr. 1). Na základě znalosti průměrného množství energie v jedné chmelové rostlině lze odhadnout celkové množství energie nahromaděné v rostlinách rostoucích na jednom hektaru chmelového porostu. V roce 1997 tak bylo v období před sklizní akumulováno u nezavlažované varianty 53,00 $GJ.ha^{-1}$ a u zavlažované varianty 64,68 $GJ.ha^{-1}$. V roce 1998 bylo u nezavlažované varianty akumulováno 44,50 $GJ.ha^{-1}$ a u zavlažované varianty 55,79 $GJ.ha^{-1}$. Zvýšení množství energie u zavlažované varianty oproti nezavlažované variantě činilo v roce 1997 11,68 $GJ.ha^{-1}$ a v roce 1998 11,29 $GJ.ha^{-1}$.

chmel; závlaha; akumulace netto energie; výnos

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