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INFLUENCE OF TEMPERATURE AND MOISTURE CONDITIONS OF LOCALITY ON THE YIELD FORMATION OF SUNFLOWER (*HELIANTHUS ANNUUS* L.)

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Abstract

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Field polyfactorial experiments were realized on fields of the Agricultural Co-operative in Nitrianska Blatnica in years 2007–2009. Experimental field is located in the maize production area (climatic region: warm; climatic sub region dry; climatic zone: warm, dry with mild winter and long sunshine) in altitude 250 m above sea level, with brown soil. We observed the influence of both temperature and moisture conditions of experimental area on sunflower yield of achenes (conventional, medium-late hybrids: NK Brio, NK Armoni). Preceding crop of sunflower (*Helianthus annuus* L.) every experimental year was wheat (*Triticum aestivum* L.). Technological system of sunflower cultivation was realized in accordance with conventional technology of cultivation. The basic fertilization was made by balance method on the base of agrochemical soil analysis for expected yield 3 $t.ha^{-1}$. The meteorological data were got out from agrometeorological station of the Central Controlling and Testing Institute in Agriculture in Veľké Ripňany. During every experimental year the change of inner energy (ΔU) was evaluated for thermodynamic characteristic analysis (security of the temperature and moisture) and the impact of changes on yield forming with maximal yield (Y_{max} in 2008) and minimal yield (Y_{min} in 2009). Achieved value of yield from thermal and precipitation energy introduces concrete energy amount, which is available in given period for concrete height of yield. From the results follow, the sunflower has got critical thermodynamic phase in the period of months from July to August. For the yield formation is requirement, that input power of precipitation prevailed over the thermal during moths July to August. Achieved results confirmed statistically high significant dependence of the yield on weather conditions and for high annual variations in climatic characteristics the consideration is needed about potential changes some agrotechnological measures of technological system of sunflower cultivation.

sunflower, thermodynamic conditions, yield of achenes

The process of yield formation of field crops is significant affected by presence and abudance of many factors, where agroecological factors are dominat, their mutual int eraction influence respectively. The influence of weather conditions is decisive in the yield formation process of oilseeds and other crops. Their interaction leads to regulation of particular growth phase, underlie the formation of quantity and quality of yield-forming elements (BRANDT *et al.*, 2003).

According to KUDRNA (1985) the inner energy (ΔU) as the criterion reviewing the influence of basic agro-climatic conditions (temperature, water, radiation, etc.) during the field crops vegetation in system solar radiation energy → phytocoenose energy, introduces this part of cell structures energy, which keeps the transformation processes on the move.

ČERNÝ *et al.* (2010) emphasize that sunflower covers create the complicated dynamic system with both soil and climatic factors, where the selected crop is considered as a less adaptive element.

The evaluation of the effect of basic climatic quantity (temperature and water) on yield formation of field crops is very complicated. Water from biologic and physiologic (PASSIOURA, 2002, 2007; CHAVES *et al.,* 2003) aspects and point of view of agroclimatic regionalization (FISCHER and TURNER, 1978; ŠPÁNIK *et al.*, 2002) is irreplaceable factor of life on the Earth. The water regime is considered as a main indicator of environment production performance (PASSIOURA, 2002).

AIKEN (2006) consider water demand as a determination factor for yield formation of field crops. The sunflower grades the requirements on the water during the vegetation period. Therefore, the disproportion between physiological requirements to the water and real precipitation in season can get to the status, which we evaluate as a water deficit.

The growth of sunflower is significantly limited under drought (MURILLO, 1998). The plant consumes of total water demand approximately 23% to the formation of head, 60% from establishment to fertilization and 17% to the full maturity. Water stress of plants affects not only reduction of yield but participates in the decrease of total oil content and oil composition in the sunflower achenes (HUSSAIN, 2008).

BRANDT *et al.* (2003) consider as a decisive climatic factor beside water also the air temperature, from which depends the soil temperature and temperature of soil solution. Sunflower's nutrients uptake depends on the soil temperature (phosphorus) and on soil moisture (ŠKARPA and LOŠÁK, 2008).

In the optimal agroecological regions the sum of active temperatures should be more than 10 °C for sunflower cultivation during growing season 120–150 days (FÁBRY, 1992). The sunflower has been increased demands on the temperature from growth stage of flowering to maturation of achenes. Therefore the average temperature should not decrease less than 18 °C at night and average daily temperature less than 24 °C during the season from July to half August. Sunflower requires average temperature more than 15 °C at night and daily more than 20 °C in the end of August and in September (BEARD and GENG, 1982).

Climatic system analysis of Slovakia (ŠPÁNIK *et al.*, 2002) show the rising of air temperature and decrease of precipitation. However, both finding and consciousness of these facts can have significant impact on decreasing of yield and quality of sunflower production (LOOMIS and CONNOR, 1992).

In the work presented we appreciate the impact of temperature and moisture conditions of experimental area on height achenes yield of sunflower (*Y*) using approach of thermo-dynamical analysis.

MATERIAL AND METHODS

Field polyfactorial experiments with sunflower (convetional, medium-late hybrids: NK Brio, NK Armoni) were realized on the experimental field of the Agricultural Co-operative in Nitrianska Blatnica. Regional agroclimatic characteristics of experimental area in years with maximal and minimal yield of achenes is given in the Tab. I.

The preceding crop of sunflower (*Helianthus annuus* L.) was winter wheat (*Triticum aestivum* L.). Basic fertilization was made using the balance method on the base of agrochemical soil analysis for yield level 3 tons per hectare. In 2008 were applied of mineral fertilizer NPK (15:15:15) in dose corresponding 45 kg $N.ha^{-1}$, 19.6 kg $P.ha^{-1}$ and 37.3 kg $K.ha^{-1}$. In 2009 were applied of mineral fertilizer NPK (8:24:24) in dose corresponding 34 kg $N.ha^{-1}$, 31.4 kg $P.ha^{-1}$ and 59.8 kg $K.ha^{-1}$.

Tillage (stubble ploughed under, deep autumn plowing), the way of setting up of sunflower (sowing date II. decade of April, spacing 0.70 × 0.22 m), treatment during the vegetation (pre-emergent herbicide application, double application of fungicides) and harvesting 2008 (Y_{max}) – III. decade of September, 2009 (Y_{min}) – I. decade of October, non-desiccated canopy, were made by conventional technology of sunflower cultivation.

Basic meteorological data (monthly precipitation in mm, average daily temperature in °C) were obtained from meteorological station of the Central Controlling and Testing Institute in Agriculture in Veľké Ripňany.

Experiments were carried out by the split plot design with randomized complete blocks base design (EHRENBERGEROVÁ, 1995). Statistical evaluation of the experimental factors was processed by the multifactor analysis of variance.

Using form to review the influence of climatic conditions is value of internal energy (ΔU).

The amount of transformed kinetic energy into potential energy is expressed:

$$T = \frac{Y_{prod}}{t_c} \qquad S = \frac{Y_{prod}}{h_s},$$

where: T is temperature coefficient and S is precipitation coefficient.

$$Y_t = T \times t_{cn} \qquad Y_{hs} = S \times h_{sn},$$

where: Y_t is term energy for yield formation; Y_{hs} is precipitation energy for yield formation; Y_{prod} is productive yield (in $t.ha^{-1}$); h_s is month precipitation sum per crop vegetation (in mm); h_{sn} is precipitation in monitored period (e.g. month, decade, pentade, etc.) (in mm); t_c is month temperature sum per crop vegetation (in °C) and t_{cn} is temperature in monitored period (e.g. month, decade, pentade, etc.) (in °C).

The yield value Y_t or Y_{hs} represents the energy quantum in system solar radiation energy, i.e. phytocenose energy (KUDRNA, 1989), which is

I: *Soil and climatic conditions of experimental locality*

Characteristics		Value	
altitude production area		250 m above sea level maize	
climatic region		warm	
climatic subregion		very dry	
climatic district		warm, dry with mild winter and long sunshine	
CLIMATIC CHARACTERISTIC			
		2008	**2009**
average air temperature	per year	10.8 °C	10.3 °C
	per vegetation	17.1 °C	18.4 °C
sum of precipitation	per year	611.4 mm	581.2 mm
	per vegetation	559.5 mm	385.8 mm
SOIL CHARACTERISTICS			
soil type		**brown soil**	
		2008	**2009**
content	available N_{an}	6.7 mg.kg^{-1}	18.1 mg.kg^{-1}
	available P	26 mg.kg^{-1}	26 mg.kg^{-1}
	available K	240 mg.kg^{-1}	285 mg.kg^{-1}
	available Ca	950 mg.kg^{-1}	500 mg.kg^{-1}
	available Mg	450 mg.kg^{-1}	480 mg.kg^{-1}
	humus	1.98 %	1.93 %
pH/KCl		5.45	6.09

defined as change of total inner energy system (*ΔU*) during time defined period for yield formation. Then, the total inner energy system change (Δ*U*) is formulated as:

$$\Delta U = \frac{Y}{t_c} t_{cn} - \frac{Y}{h_s} h_{sn} = T \times t_{cn} - S \times h_{sn} = Y_t - Y_{hs} \ .$$

RESULTS AND DISCUSSION

The formation of sunflower yield is significantly affected by both temperature and moisture requirements during the vegetation. Thermodynamic conditions of individual experimental years were differentiated by temperature and moisture conditions (Tab. II). In year 2008, due to yield of achenes was highest (Y_{max} = 3.81 t.ha^{-1}), the course of weather conditions was most favorable for formation of sunflower yield during individual growth seasons (precipitation per vegetation was 559.5 mm; average temperature was 17.1 °C). In year 2009, where was achieved the lowest yield (Y_{min} = 3.13 t.ha^{-1}), the tendency of weather conditions in comparison with physiological optimum is less shining (precipitation per vegetation is 385.8 mm; average temperature is 18.4 °C).

Increasing of achene yield is influenced not only by total precipitations but also their uniform distribution during vegetation period, i.e. during growth stages, when the crop used them effectively. The sunflower requires higher precipitation during the formation of assimilatory apparatus

II: *The thermal and moisture conditions for creation of sunflower inner energy in years with maximum and minimum yield*

Month	Normal (n) 1961–1990		Optimal requirement (i)		Y_{max} 3.81 t.ha^{-1} (2008)		Y_{min} 3.13 t.ha^{-1} (2009)	
	Σ_{mm}	X_{td} °C	Σ_{mm}	X_{td} °C	Σ_{mm}	X_{td} °C	Σ_{mm}	X_{td} °C
IV.	39.0	10.4	27.5	10	89.3	10.9	30	14.8
V.	58.0	15.1	77.6	12	95.8	16.3	86.1	16.1
VI.	66.0	18.0	13.6	16	53.7	20.1	92.7	18.1
VII.	52.0	19.8	14.6	19	15.5	20.5	85.1	22.1
VIII.	61.0	19.3	95.4	18	63.8	19.9	59.8	21.6
IX.	40.0	15.6	12.2	15	10.9	14.4	32.1	17.7

Where Σ_{mm} is sum of precipitation; X_{td} °C is average daily air temperature and Y_{max} and Y_{min} are minimal and maximal yield of achenes, respectively.

with maximum in growth stage of flowering and formation of heads, i.e. during July in our region. Deficit of precipitation influenced on metabolism process deregulatory in the season of increased physiological moisture requirement, which increased differences between potential and real yield of achenes (CRITHLEY *et al.*, 2003).

The differences between achene yields were significantly influenced not only with precipitation but also with temperatures. Higher values in comparison with long-term normal (1961–1990) are caused by increased transpiration and evapotranspiration; it impacts on total nutrient uptakes and performance of assimilation. Increase of precipitation with rising daily temperatures into the level of appropriate conditions to growth and development is decisive for yield formation. On the other hand, for yield formation of achenes in the end of vegetation period is appropriate gradual decline of average temperatures and precipitations (FÁBRY, 1982), which confirmed partially our results of changes of inner energy.

KUDRNA (1985) presents, that maximal yield of many crops are reached in conditions of maximal growth intensity and high stability between biological processes and climatic factors. The optimal running of the biological processes in the plant cells needs concrete thermo-dynamical conditions in various phases of growth and development. Maximal dry matter accumulation is defined by maximal accumulation of systems inner energy. Metabolic activity as aspects of systems inner energy is deactivated under deficit of precipitation in conditions without irrigation which results in sunflower yield decrease. KUDRNA (1985) consider the change of an inner energy (ΔU) as a basic criterion of energy transformation of thermodynamic characteristics.

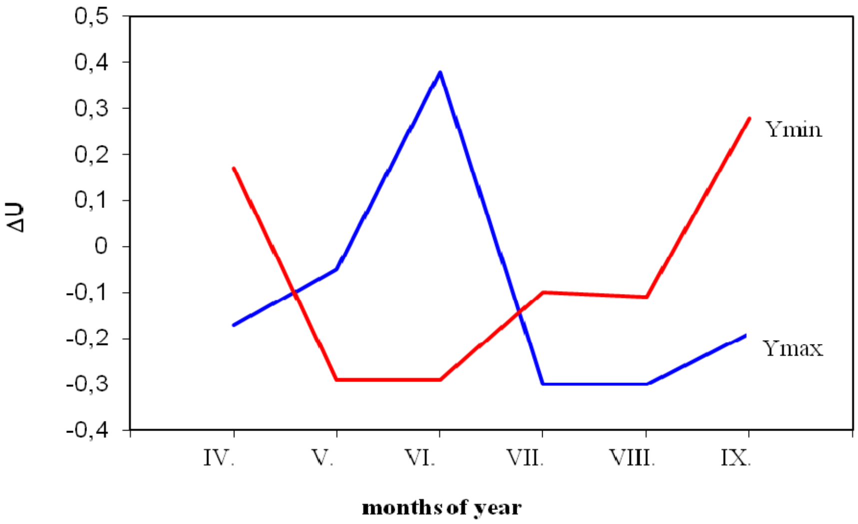
From the point of maximal yield of achenes formation it is important that the values of inner energy should be negative during the critical thermo-dynamical growth. It means that during formation of achenes is predominates the energy input from precipitation (Y_{hs}) over the energy input from temperatures (Y_t). Balance changes between both temperatures and precipitation cause the disproportion in reached yields.

Critical period of growing and development of the sunflower shows a maximal intensity of growing heads and achenes. For formation of maximal yield

III: *Changes of inner energy for ΔU for sunflower*

Month	Y_{max} 3.81 t.ha^{-1} (2008)			Y_{min} 3.13 t.ha^{-1} (2009)		
	Y_t	Y_{hs}	ΔU	Y_t	Y_{hs}	ΔU
IV.	0.40	0.61	0.17	0.44	0.27	0.17
V.	0.60	0.65	0.5	0.48	0.77	–0.29
VI.	0.74	0.36	0.38	0.54	0.83	–0.29
VII.	0.75	1.05	0.30	0.66	0.76	–0.10
VIII.	0.73	0.43	0.30	0.64	0.53	–0.11
IX.	0.53	0.69	0.19	0.53	0.28	0.28

Where Y_t is temperature energy needed to yield formation; Y_{hs} is precipitation energy needed to yield formation and ΔU is change of inner energy.



1: *The Characteristic thermodynamic curve lines of inner energy (ΔU) calculated for maximal and minimal yield of sunflower* of achenes is essential to achievement of maximal change of inner energy (ΔU) by both maximal temperatures and precipitation. The course of characteristic curves confirms in individual months of vegetation period, that critical periods with lowest values of inner energy are connected with intensive growth of field crops. This period is predestined to temperature gradients, when the plant grows intensively. Calculated changes on the level of ΔU and their influence on yield formation are given in Tab III and in Fig. 1 by thermodynamic curve lines.

Analyzed data show the real situation of changes of inner energy on axis of coordinates for vegetation period of sunflower, where prevailed the influence of precipitation over temperatures forming Y_{max} and Y_{min}, respectively. To formation of the maximal yield of sunflower was found more significant influence of precipitation in July and August. On the other hand, the values of inner energy relating to the minimal yield formation show on shift of period with prevailing influence of precipitation over the temperatures in May and June and dominance of temperatures in August, which we consider as an important fact in this thermo-dynamical analysis.

SUMMARY

From the point of yield formation the analysis of thermodynamic locality conditions represents one from alternatives for study of production process forming of field crops. The aim of work is show the impact of both temperature and moisture conditions on sunflower yield of achenes from experiment results of years 2007–2009 (Y).

From analysis of thermodynamic conditions of sunflower cultivation results, that maximal yield of achenes (Y_{max}) was achieved in the year 2008, the precipitation was 559.5 mm during the vegetation period and average temperature was 17.1 °C. The lowest yield (Y_{min}) was found in the year 2009, where the precipitation was only 385.8 mm and average temperature was 18.4 °C. The difference between the precipitations in experimental years was 173.7 mm and between yields of achenes is 0.68 t.ha^{-1}. The value of inner energy (ΔU) was negative for the formation of maximal yield (2008) in critical growth periods. On the other hand, the input power of thermal energy dominated over precipitation formed of minimal yield (Y_{min}). In year with maximal yield (Y_{max}) the sunflower showed higher requirements on moisture in July and August, but in May and June in year with minimal yield.

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